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ATOMIC DATA FOR FUSION

VOLUME V

"COLLISIONS OF CARBON AND OXYGEN IONS WITH ELECTRONS, H, H_2 AND He"

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SERIES PREFACE

The primary objective of the Controlled-Fusion Atomic Data Center at Oak Ridge National Laboratory is to publish handbooks containing numerical and graphical cross sections and other physical data relevant to fusion energy research. In 1977, a two-volume compilation was published as ORNL reports ORNL-5206 and ORNL-5207. Since that time, a large volume of pertinent data has become available, necessitating an update of the previous compilation. Plans are to include both cross sections and rate coefficients for collisional processes, and to publish the revised series in handbook form. The specific volumes which are in preparation are listed below, with their expected completion dates.

Vol. 1, "Collisions of H, H_2, He, and Li Atoms and Ions with Atoms and Molecules," C. F. Barnett, ORNL (January 1988).

Vol. 2, "Collisions of Electrons with Atoms and Molecules," J. W. Gallagher, Joint Institute for Laboratory Astrophysics; and C. F. Barnett, ORNL (October 1988).

Vol. 3, "Particle Interactions with Surfaces," E. W. Thomas, Georgia Institute of Technology (February 1985).

Vol. 4, "Spectroscopic Data for Iron," W. L. Wiese, National Bureau of Standards (February 1985).

Vol. 5, "Collisions of Carbon and Oxygen Ions with Electrons, H, H_2, and He," R. A. Phaneuf, ORNL; R. K. Janev, Institute of Physics, Belgrade; and M. S. Pindzola, Auburn University. (February 1987)

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ATOMIC DATA FOR FUSION

VOL. 5

COLLISIONS OF CARBON AND OXYGEN IONS WITH ELECTRONS, H, H_2, AND He

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ABSTRACT

This report provides a handbook for fusion research of recommended cross-section and rate-coefficient data for collisions of carbon and oxygen ions with electrons, hydrogen atoms and molecules, and helium atoms. Published experimental and theoretical data have been collected and evaluated, and recommended data are presented in tabular, graphical, and parametrized form. Processes considered include excitation, ionization, and charge exchange at collision energies appropriate to applications in fusion-energy research.

INTRODUCTION

This volume contains recommended cross section data for inelastic collisions of carbon and oxygen ions with electrons, H, H_2, and He. The following processes have been considered: one-electron capture (single charge transfer), single ionization and excitation of H, H_2, and He in collisions with C^{q+} and O^{q+} ions ($1 \leq q \leq Z$, Z being the nuclear charge), and single ionization and excitation of C^{q+} and O^{q+} ions [$1 \leq q \leq (Z-1)$] by electron impact.

Reaction rate coefficients have also been calculated from the recommended cross sections for the case of Maxwellian velocity distributions for both reactants, where each reactant species may be characterized by a different temperature. Where applicable, rate coefficients are also calculated for the case of neutral monoenergetic beams incident upon a Maxwellian plasma. The ranges of Maxwellian temperatures and beam energies were determined and constrained both by the availability of cross section data and by the parameters characterizing present-day and proposed reactor fusion plasmas. Least-squares Chebychev (or Chebyshev) polynomial fitting parameters are given for both the recommended cross sections and the deduced rate coefficients. In the case of electron-impact ionization, analytical fits are given for the cross section. Practical details on the least-squares fits and procedures and sample computer programs for generating the cross sections and rates from them are presented in the Appendix.

The experimental and theoretical data which form the basis for the recommended cross sections and rate coefficients contained in this volume were those available as of August 15, 1985. The bibliographic files of the ORNL Controlled Fusion Atomic Data Center provided the lists of references for this volume. In the vast majority of cases, the numerical data were obtained directly from the original publications, either from tables where available, or from figures using a precision graphical digitizer system. The rms uncertainty associated with this digitization system was determined to be less than 2%. A number of published data compilations were particularly useful as secondary data sources, and for checks of completeness and consistency. A list of these compilations is given at the end of this introductory section.

The estimated accuracies were determined from those quoted in the original data sources when available. In those collision systems or collision energy ranges where more than one experiment, or where a combination of theory and experiment, or a number of theoretical calculations were available, uncertainties were additionally determined by the consistency of the data available. To determine the recommended cross section, relative weightings were made on the basis of the reliability of the experimental method used, the degree of sophistication of the theoretical calculations, or the applicability of a theoretical method in a given energy range. In

some cases, the possible effects on the measurements of other physical mechanisms or collision processes were considered in determining the recommended cross section and its uncertainty. In all cases, the accuracies are believed to have been conservatively estimated, and are intended to represent upper limits on the uncertainty of the recommended cross sections.

References to Recent Data Compilations Used in the Preparation of This Report

I.1. "Cross Sections for Charge Transfers of Highly Ionized Ions in Hydrogen Atoms," H. Tawara, T. Kato, and Y. Nakai, Institute of Plasma Physics, Nagoya University Report IPPJ-AM-30, Japan (August 1983).

I.2. "Cross Sections for Electron Capture and Loss by Positive Ions in Collisions with Atomic and Molecular Hydrogen," H. Tawara, T. Kato, and Y. Nakai, Atomic Data and Nuclear Data Tables 32, 235 (August 1985).

I.3. "Electron Capture and Loss Cross Sections for Collisions Between Heavy Ions and Hydrogen Molecules," H. Tawara, T. Kato, and Y. Nakai, Institute of Plasma Physics, Nagoya University Report IPPJ-AM-28, Japan (June 1983).

I.4. "Total Cross Sections for Electron Capture by Multiply Charged Ions in H, H_2, and He," B. A. Huber and H. J. Kahlert, Rühr-Universität Bochum Report No. 82-05-104, West Germany (October 1982).

I.5. "Evaluated Theoretical Cross Section Data for Charge Exchange of Multiply Charged Ions and Atoms," R. K. Janev, J. W. Gallagher, and B. H. Bransden, JILA Information Center Report No. 25, University of

Colorado, Boulder (May 1984); J. Phys. Chem. Ref. Data 12, 829 (1983); ibid. 12, 873 (1983); ibid. 13, 1199 (1984).

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I.7. "Recommended Data on Excitation of Carbon and Oxygen Ions by Electron Collisions," Y. Itikawa, S. Hara, T. Kato, S. Nakazaki, M. S. Pindzola, and D. H. Crandall, Institute of Plasma Physics, Nagoya University Report IPPJ-AM-27, Japan (June 1983); Atomic Data and Nuclear Data Tables 33, 149 (1985).

I.8. "Ionization Cross Sections of Atoms and Ions by Electron Impact," H. Tawara, T. Kato, and M. Ohniski, Institute of Plasma Physics, Nagoya University Report IPPJ-AM-37, Japan (February 1985).

I.9. "Atomic and Molecular Data for Fusion, Part I - Recommended Cross Sections and Rates for Electron Ionisation of Light Atoms and Ions," K. L. Bell, H. B. Gilbody, J. G. Hughes, A. E. Kingston, and F. J. Smith, Culham Laboratory Report CLM-R216, Abingdon, Oxfordshire, United Kingdom (1982); J. Phys. Chem. Ref. Data 12, 891 (1983).

I.10. "Report on Recommended Data (for Electron-Impact Excitation)," K. M. Aggarwal, K. A. Berrington, W. B. Eissner, and A. E. Kingston, Atomic Data Workshop, Daresbury Laboratory, United Kingdom (March 1986).

I.11. "An Evaluated Compilation of Data for Electron-Impact Excitation of Atomic Ions," J. W. Gallagher and A. K. Pradhan, JILA Information Center Report No. 30, University of Colorado, Boulder, Colorado (1985).

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1. CHARGE EXCHANGE IN COLLISIONS OF C^{q+}, O^{q+} (q=1-Z) WITH H, He, AND H_2

1.1 General Remarks

The electron capture reactions

$$A^{q+} + B \rightarrow A^{(q-1)+} (n,\ell) + B^{+} , \tag{1.1}$$

where A = C, O, and B = H, He, H_2 are all characterized by large cross sections and selective population of final (n,ℓ) states. For $q > 2$ and collision energies $E \lesssim 25$ keV/amu reactions (1.1) proceed dominantly through strong coupling of initial and final state configurations in the regions where the corresponding potential energy curves have pseudo crossings. With increasing q, the number of strongly coupled reaction channels increases dramatically. This makes detailed cross section calculations difficult, even with existing computational capabilities. In the energy region above 25 keV/amu, the role of the ionization channel becomes increasingly important and the need for inclusion of the coupling with continuum states further complicates the theoretical treatment. For q = 1, transitions producing reactions (1.1) at low energies are induced by the exponentially small configurational coupling and, unless the reaction energy defect is small (like in the O^{+} + H case), the capture probability is adiabatically small (as in the case of O^{+} + He collisions). Detailed information on the theoretical methods for calculation of cross sections of charge exchange reactions of the type (1.1) can be found in the monograph [G.1] and in several review articles

[G.2]-[G.4]. The experimental methods for investigation of charge exchange processes involving multiply charged ions have also been presented in several review articles [G.5]-[G.8]. As a result of numerous studies of charge exchange reactions of the type (1.1), both experimental and theoretical, many general features of the total cross sections for these reactions have been established. Below we give a brief account of them, which will help to understand in general terms the behavior of the total single charge exchange cross sections [i.e., the sum of cross sections for individual $A^{(q-1)+}$ (n,ℓ) final states] presented in the subsequent sections. Specific features for each particular reaction will be given in the notes accompanying the actual cross section data.

1.1.1 Energy dependence of the cross section

The energy dependence of total charge exchange cross section depends on the specific collision dynamics for each particular reaction in a given energy region (i.e., on the electronic structure of colliding particles, collision velocity and ionic charge), and is, therefore, nonuniform. Only in the high-energy limit ($E \gg 25\sqrt{q}$ keV/amu), where the capture process is dominated by the electron-ion interaction, the cross section has an $E^{-11/2}$ behavior [G.9]. In the region below ~25 $\sqrt{q}$ keV/amu, the energy behavior of total cross section is determined by the predominance of one or several partial cross sections (for capture into particular states),

whose maxima appear in different regions on the energy scale. When the capture can occur into many final states, the cross section has a broad maximum, sometimes forming a plateau (e.g., in the O^{7+} + H case). In the thermal energy region ($E < 0.03$ eV), the capture is dominated by the Langevin orbiting mechanism (polarization capture), and the cross section is approximately given by

$$\sigma_{orb}(q) = \pi q \left(\frac{2\alpha}{E_{cm}}\right)^{1/2} (a_0{}^2) \tag{1.2}$$

where α is the dipole polarizability of the target and a_0 is the Bohr radius. For C^{q+}, O^{q+} + H collisions ($\alpha = 4.5\ a_0{}^3$) the corresponding reaction rate coefficient is about $0.85\ q \times 10^{-7}$ cm^3/sec.

1.1.2 q-Dependence of total cross sections

Since in various energy regions the mechanisms governing the capture process are different, the cross section dependence on ionic charge is also varying with energy E. If we represent the total cross section in the form

$$\sigma_{ex} = \sigma_o(E)\ q^{\beta(E)} \tag{1.3}$$

where $\sigma_o(E)$ is the q-independent part of σ_{cx}, then the scaling parameter $\beta(E)$ varies, between the values $\beta = 1.07$, valid for $E \lesssim 25\sqrt{q}$ keV/amu, and the value $\beta = 5$, in the high energy limit (say, for $E \gtrsim 10\sqrt{q}$ MeV/amu). In the region between ~250 keV/amu and several MeV/amu the value of $\beta \simeq 3$ has been found. The above scaling properties of σ_{cx} follow from both

theoretical and experimental investigations. (More detailed information on the q-scaling can be found elsewhere [G.1], [G.3], [G.10].) The linear scaling of σ_{cx} in the low energy region breaks down for low charge-state ions ($q \lesssim 6$) due to the selectivity of the capture process and discrete character of product ion energy levels. The q-dependence of the total cross section at fixed velocity in this (q,E) domain exhibits characteristic oscillations (see [G.1], [G.3], [G.11]).

1.1.3 Capture into specific final states

Although the information about the partial cross sections for electron capture into specific final ionic states is of great importance for fusion plasma diagnostics and radiation loss calculations, the data on these cross sections are very sparse at present. The existing data for the reaction systems considered are highly incomplete, cover limited energy regions, and in most cases have large uncertainties. Therefore, we deemed that it is premature to undertake evaluation and presentation of these data at the present stage. Nevertheless, in the notes for each particular reaction, we give the references where information on state-selective electron capture can be found, and comment on the role of various final reaction channels in the capture process. The existing information on state-selective electron capture is given in a recent review [G.12]. Here we confine ourselves to a few remarks. The partial cross sections for population of different final states

have maxima at different collision energies, which may produce a "structure" in the total cross section. For capture from atomic H, there is experimental and theoretical evidence that in the region below ~50 $\sqrt{q}$ keV/amu, the principal quantum number of preferentially populated final state is ([G.3], [G.13]):

$$n_m = \text{Int}\,[n_o q^{0.768}] \equiv n^* \tag{1.3}$$

where n_o is the effective principal quantum number of the electron in its initial state, and Int [x] denotes the closest integer to x. For energies above ~100 $\sqrt{q}$ keV/amu, n_m becomes energy-dependent and smaller than n^*. In the high-energy limit capture goes dominantly to the ground state of $A^{(q-1)+}$ ion. The other principal final shells in this limit are populated according to the n^{-3} Oppenheimer scaling [G.9]. In the general case of a many-electron target and an incompletely stripped projectile, no general rules can be established for the distribution of captured electrons over the orbital angular momentum (ℓ) states. In a given energy region, the dominantly populated (n,ℓ) state is that which is in quasi-resonance with the initial state. For the hydrogen atom - fully stripped ion collision system, the existing theoretical and experimental information leads to the following conclusions: (a) In the very low energy region (approaching thermal energies), the dominantly populated substate is that with $\ell_m = 1$ (if the transition is dominated by a $\sigma - \sigma$ radial

coupling). At higher energies [including the intermediate region, E ~(25-100) $\sqrt{q}$ keV/amu], the ℓ-distribution of captured electrons (within a given n-shell) has maximum at ℓ_m = n-1, if $n < n_m$, and $\ell_m \simeq n_m < (n-1)$, if $n > n_m$. [It is characteristic that the population of the substates $\ell \approx n-1$ in the case $n < n_m$ is higher than the one expected from a statistical distribution.] In the high-energy limit, the $\ell = 0$ substate is the most populated. There is some evidence [G.14], that the above rules also apply for incompletely stripped ions having a closed shell configuration (such as C^{4+} and O^{6+}).

1.1.4 Capture from He and H_2 targets

The two-electron structure of He and H_2 targets brings some additional aspects into the single electron capture process. First of all, two-electron transition processes (such as double electron capture and simultaneous capture and ionization) become possible, particularly with increasing the ionic charge. Then new reaction channels further complicate the collision dynamics and make theoretical treatments more difficult. From an experimental point of view, identification of reaction channels requires use of coincidence techniques, since, for instance, both single capture and capture-ionization (or double capture into an autoionizing state) lead to reduction of projectile charge by one. For the considered C^{q+}, O^{q+} + He, H_2 collision systems, the coupling of single electron

capture channel with the two-electron transition processes has not been investigated in detail. Exceptions are the C^{4+} + He and O^{8+} + He systems (see Sects. 1.4 and 1.5), for the first of which it has been established that double capture is a dominant process in the region below ~1 keV/amu. In the case of C^{q+}, O^{q+} + H_2 collisions, the single electron capture may be significantly influenced by vibrational excitations of H_2. In general, electron capture in this case may be accompanied by electronic excitation of the product target ion, which may lead to dissociation.

The experimental difficulties in charge exchange cross section measurements on atomic hydrogen have raised the question of the relation between the total charge exchange cross sections for H_2 and H targets (see e.g., [G.15]). A frequent assumption in the past was that in the high-energy region, $\sigma_{cx}(H_2) \simeq 2\sigma_{cx}(H)$. A recent analysis of numerous experimental data for $\sigma_{cx}(H_2)$ and $\sigma_{cx}(H)$ has led to the following empirical scaling, [G.16]:

$$\frac{\sigma_{cx}(H_2)}{\sigma_{cx}(H)} = \begin{array}{l} 0.76 \ , \ X < 6 \ , \\ 0.76 + 0.0328\,(X-6) \ , \ 6 < X < 100 \ , \\ 3.84 \ , \ X > 100 \ , \end{array} \qquad (1.4)$$

where

$$X = q^{-4/7}\ E\ (\text{keV/amu}) \qquad (1.5)$$

At an 80% confidence level, the above scaling fits the available experimental data to within ±20% accuracy. We have used the relation (1.4) to extend data to higher energies for some C^{q+}, O^{q+} + H_2 cases (see Sects. 1.6 and 1.7).

1.1.5 Experimental methods

The total charge exchange cross section measurements for the cases evaluated here have been obtained almost exclusively by the fast ion beam - gas target technique. Charge/mass selected ion beams are directed through a differentially-pumped collision cell containing the relevant target gas. The charge state distribution of the ion beam emerging from the target cell is analyzed either magnetically or electrostatically using spatial dispersion or deceleration techniques. The charge exchange cross section is deduced from the variation with target gas density of the fraction of ions which have captured an electron under single-collision conditions. Key experimental parameters to be measured are the target density or pressure and effective physical length of the target cell. The density has in some cases been determined by pressure measurement, and in other cases the density-length product (target thickness π) is deduced by normalizing to some well-established cross section for some other ion which can be directed through the target. Atomic hydrogen gas targets have been produced by thermal dissociation at ~2300 K in hot tungsten furnaces, or by directing the ion beam through the gas effusing from an rf discharge tube. The effective degree of dissociation of H_2 can be high (~90%), but must be determined experimentally (usually by the double-electron-capture technique). Thus the effective target thicknesses of both H

and H_2 must be determined. This has been accomplished in all cases by normalization to well-established capture cross sections. The normalization of most of the atomic hydrogen cross section data considered herein is traceable to cross sections for $H^+ + H$ and $H^+ + H_2$ or $He^{2+} + H_2$ which are known to 5-10%.

Measurements have also been made on atomic hydrogen using a crossed-beams coincidence technique, in which a fast ion beam was crossed by a beam of H atoms emerging from a thermal-dissociation atomic hydrogen target [G.23]. Electron capture and target-ionization events were distinguished by detection of the fast and slow product ions in coincidence. The composition and target thickness of the H beam was determined by the methods described above.

Transfer ionization (double electron capture followed by autoionization) is also possible for He and H_2 targets. In experiments where the capture cross sections are determined by charge analysis of the fast ion products, this contribution is registered as part of the total single electron capture cross section. This contribution is relatively small for most of the collision systems considered here, and has been taken into consideration in making estimates of uncertainties in the recommended cross sections.

1.1.6 Role of ionic metastable states

Ion beams produced in both electron-impact and plasma-discharge-type ion sources are known to contain some fraction

of ions in (particularly low-lying) metastable states. This is also expected to be the case for the higher-energy multiply charged ion beams produced by foil- or gas-stripping. In only two specific cases covered here (C^+ and O^+) has this situation been addressed directly in charge exchange experiments, and metastable fractions estimated. In all cases, the recommended cross-section curves are taken to represent mixtures of initial ionic ground and metastable states which are characteristic of ion sources, and of the plasmas for which these recommended data are intended.

Li-like ions (C^{3+}, O^{5+}) have no metastable levels (except for extremely high lying autoionizing states which are weakly populated). H-like ions in the 2s metastable state are expected to decay by 2s-2p mixing in the analyzing fields present in most of the experiments.

Experimental data are now becoming available for state-selective electron-capture cross sections for multiply charged ions. These cross sections have been obtained either by translational energy-gain or by optical spectroscopic methods. As noted in Sect. 1.1.3, these data were considered too sparse at the present time for inclusion in this compilation of recommended cross sections. However, the notes for each set of reactants contain information on the expected final (n,ℓ) state distributions where available, and references to specific papers for those cases where experimental or theoretical data are known to exist.

Total Electron Capture Cross Sections for
$C^+ + H \rightarrow C + H^+$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
5.0E+01	9.82E+06	7.54E-17
7.0E+01	1.16E+07	9.13E-17
1.0E+02	1.39E+07	1.07E-16
2.0E+02	1.96E+07	1.41E-16
4.0E+02	2.78E+07	2.52E-16
7.0E+02	3.68E+07	4.78E-16
1.0E+03	4.39E+07	6.50E-16
2.0E+03	6.21E+07	8.29E-16
4.0E+03	8.79E+07	8.06E-16
7.0E+03	1.16E+08	7.22E-16
1.0E+04	1.39E+08	6.10E-16
2.0E+04	1.96E+08	3.91E-16
4.0E+04	2.78E+08	1.92E-16
7.0E+04	3.68E+08	6.94E-17
1.0E+05	4.39E+08	2.81E-17
2.0E+05	6.21E+08	3.67E-18
3.3E+05	7.93E+08	5.63E-19

References: E.1, E.2, E.3, T.1, T.2

Accuracy: 20% for $50 \leq E(eV/amu) \leq 1.5 \times 10^5$; 20-50% for $E > 1.5 \times 10^5$ eV/amu

Note: A rate coefficient of $\alpha = 1.4 \times 10^{-17}$ cm^3/s has been calculated at $T = 10^4$ K [T.2], which corresponds to a cross section of $\sigma \sim 10^{-23}$ cm^2 at $E \simeq 0.86$ eV/amu. Although the accuracy of this data is within a factor of 3 to 5, it suggests a rapid fall-off of σ when E decreases below 50 eV/amu. This behavior was taken into account in calculations of rate coefficients at low T.

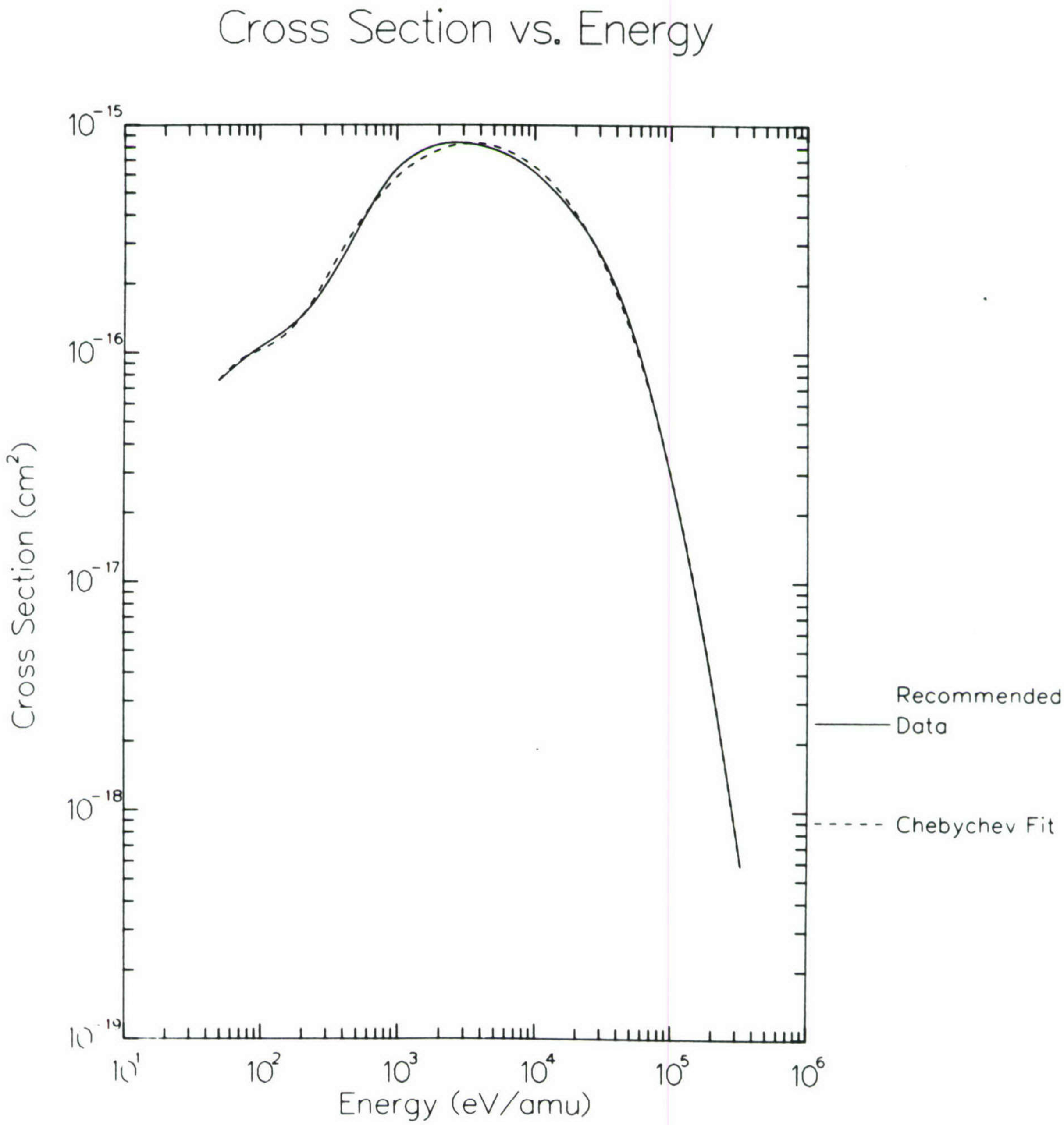
For Chebychev fits of the above cross sections it is necessary to use the following parameters.
E_{min} = 5.0E+01 eV/amu, E_{max} = 3.3E+05 eV/amu

Chebychev Fitting Parameters for Cross Sections

C1	C2	C3	C4	C5	C6	C7	C8	C9
4.989E-16	-5.751E-17	-3.336E-16	2.319E-17	1.752E-16	-9.867E-18	-6.189E-17	7.315E-18	8.234E-18

The fit represents the above cross sections with an rms deviation of 5.2%.
The maximum deviation is 11.7% at 4.0E+02 eV/amu.
See appendix for Chebychev fit details.

$C^{+} + H \rightarrow C + H^{+}$



Total Electron Capture Rate Coefficients for
$C^{+} + H \rightarrow C + H^{+}$

Maxwellian - Maxwellian Rate Coefficients (cm^3/s)

C^{+} Temp. (eV)	Equal Temp.	H Temp. (eV) 1.	10.	100.	1000.	5000.	10000.	20000.
4.8E+01	1.12E-09	4.06E-11	2.36E-10	2.46E-09	3.44E-08	6.98E-08	7.21E-08	6.24E-08
8.4E+01	2.09E-09	9.77E-11	3.08E-10	2.55E-09	3.45E-08	6.98E-08	7.21E-08	6.24E-08
1.2E+02	3.28E-09	1.65E-10	3.81E-10	2.64E-09	3.46E-08	6.98E-08	7.21E-08	6.24E-08
2.4E+02	8.40E-09	4.05E-10	6.19E-10	2.95E-09	3.48E-08	6.98E-08	7.21E-08	6.24E-08
6.0E+02	2.39E-08	1.10E-09	1.31E-09	3.97E-09	3.56E-08	6.99E-08	7.21E-08	6.23E-08
8.4E+02	3.20E-08	1.57E-09	1.80E-09	4.71E-09	3.61E-08	6.99E-08	7.21E-08	6.23E-08
1.2E+03	4.11E-08	2.37E-09	2.64E-09	5.89E-09	3.68E-08	7.00E-08	7.21E-08	6.23E-08
2.4E+03	5.84E-08	5.93E-09	6.30E-09	1.01E-08	3.90E-08	7.02E-08	7.20E-08	6.22E-08
4.8E+03	7.02E-08	1.44E-08	1.48E-08	1.84E-08	4.30E-08	7.06E-08	7.19E-08	6.20E-08
8.4E+03	7.25E-08	2.57E-08	2.60E-08	2.88E-08	4.81E-08	7.11E-08	7.17E-08	6.16E-08
1.2E+04	6.98E-08	3.43E-08	3.46E-08	3.68E-08	5.22E-08	7.15E-08	7.15E-08	6.13E-08
2.0E+04	6.07E-08	4.75E-08	4.76E-08	4.90E-08	5.89E-08	7.22E-08	7.10E-08	6.06E-08

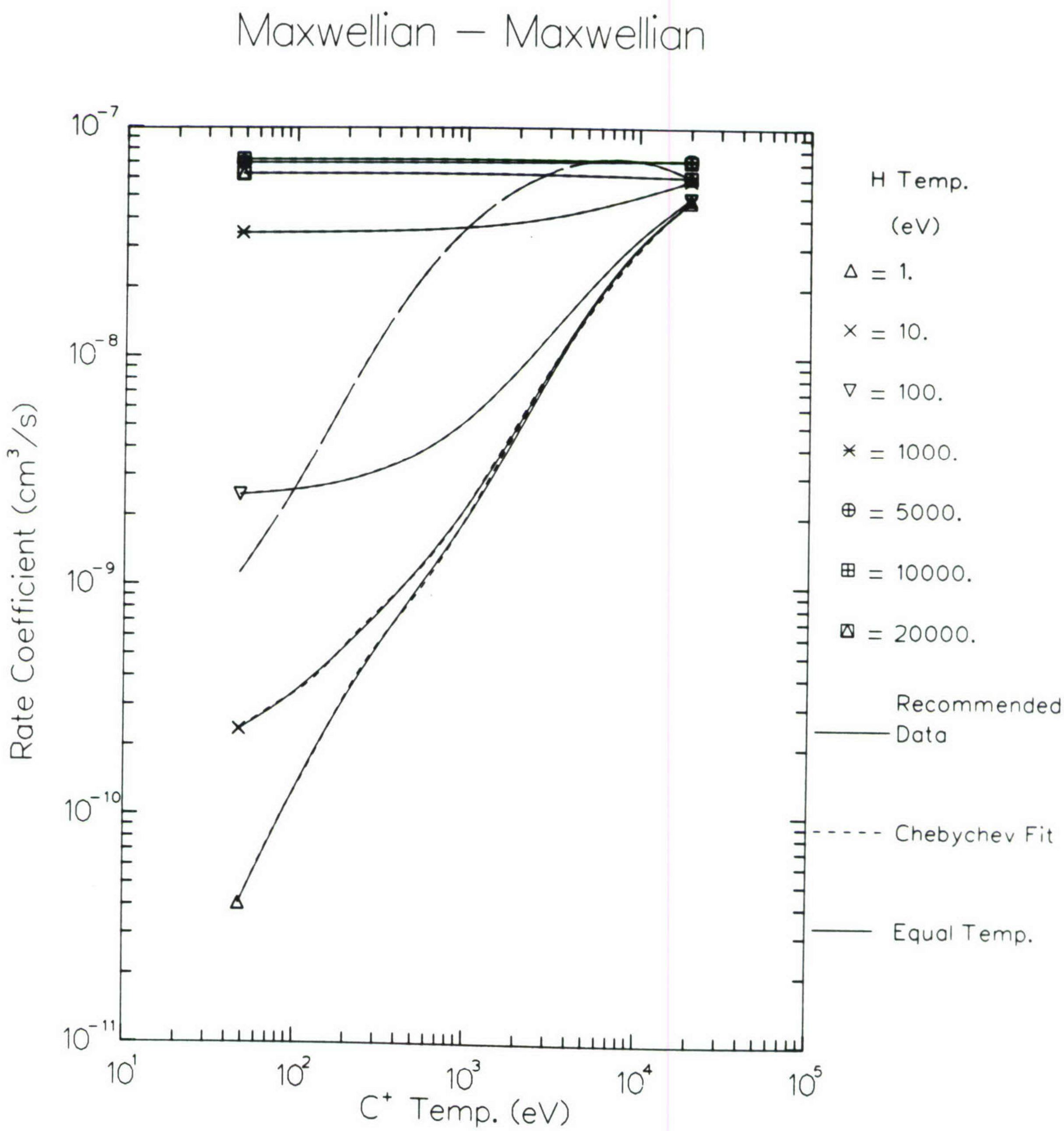
Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 4.8E+01 eV, E_{max} = 2.0E+04 eV

Chebychev Fitting Parameters for Rate Coefficients

H Temp. (eV)	C1	C2	C3	C4	C5	C6	C7
1.	2.542E-08	2.076E-08	1.143E-08	3.961E-09	4.393E-10	-3.370E-10	-1.523E-10
10.	2.589E-08	2.075E-08	1.130E-08	3.776E-09	2.705E-10	-4.344E-10	-1.885E-10
100.	3.090E-08	2.072E-08	1.048E-08	2.995E-09	-1.066E-11	-4.362E-10	-1.755E-10
1000.	8.273E-08	1.082E-08	5.220E-09	1.524E-09	1.318E-10	-1.100E-10	-6.651E-11
5000.	1.409E-07	1.055E-09	5.203E-10	1.559E-10	1.439E-11	-1.384E-11	-9.706E-12
10000.	1.438E-07	-4.313E-10	-2.618E-10	-1.280E-10	-5.361E-11	-2.080E-11	-7.884E-12
20000.	1.239E-07	-7.127E-10	-4.050E-10	-1.734E-10	-5.861E-11	-1.623E-11	-3.746E-12
Equal Temp.	7.115E-08	3.946E-08	-2.767E-09	-1.080E-08	-2.262E-09	1.163E-09	3.938E-10

See appendix for Chebychev fit details

$C^+ + H \rightarrow C + H^+$



Total Electron Capture Rate Coefficients for
$H + C^{+} \rightarrow C + H^{+}$

Beam - Maxwellian Rate Coefficients (cm^3/s)

C^{+} Temp. (eV)	H Energy (eV/amu) 10000.	20000.	40000.	70000.	100000.	200000.	500000.
4.8E+01	8.48E-08	7.68E-08	5.33E-08	2.55E-08	1.24E-08	2.28E-09	5.20E-11*
8.4E+01	8.48E-08	7.67E-08	5.32E-08	2.55E-08	1.24E-08	2.28E-09	5.22E-11*
1.2E+02	8.48E-08	7.67E-08	5.32E-08	2.55E-08	1.24E-08	2.28E-09	5.23E-11*
2.4E+02	8.47E-08	7.67E-08	5.32E-08	2.55E-08	1.24E-08	2.28E-09	5.26E-11*
6.0E+02	8.47E-08	7.65E-08	5.30E-08	2.55E-08	1.24E-08	2.28E-09	5.33E-11*
8.4E+02	8.46E-08	7.65E-08	5.30E-08	2.55E-08	1.24E-08	2.28E-09	5.36E-11*
1.2E+03	8.44E-08	7.64E-08	5.29E-08	2.55E-08	1.24E-08	2.28E-09	5.40E-11*
2.4E+03	8.42E-08	7.60E-08	5.27E-08	2.55E-08	1.24E-08	2.28E-09	5.51E-11*
4.8E+03	8.35E-08	7.55E-08	5.22E-08	2.55E-08	1.25E-08	2.29E-09	5.67E-11*
8.4E+03	8.25E-08	7.49E-08	5.19E-08	2.55E-08	1.26E-08	2.30E-09	5.86E-11*
1.2E+04	8.16E-08	7.41E-08	5.14E-08	2.56E-08	1.27E-08	2.32E-09	6.01E-11*
2.0E+04	7.98E-08	7.27E-08	5.07E-08	2.57E-08	1.30E-08	2.36E-09	6.32E-11*

Accuracy: * - Possible Error Greater Than 10%
** - Possible Error Greater Than 100%

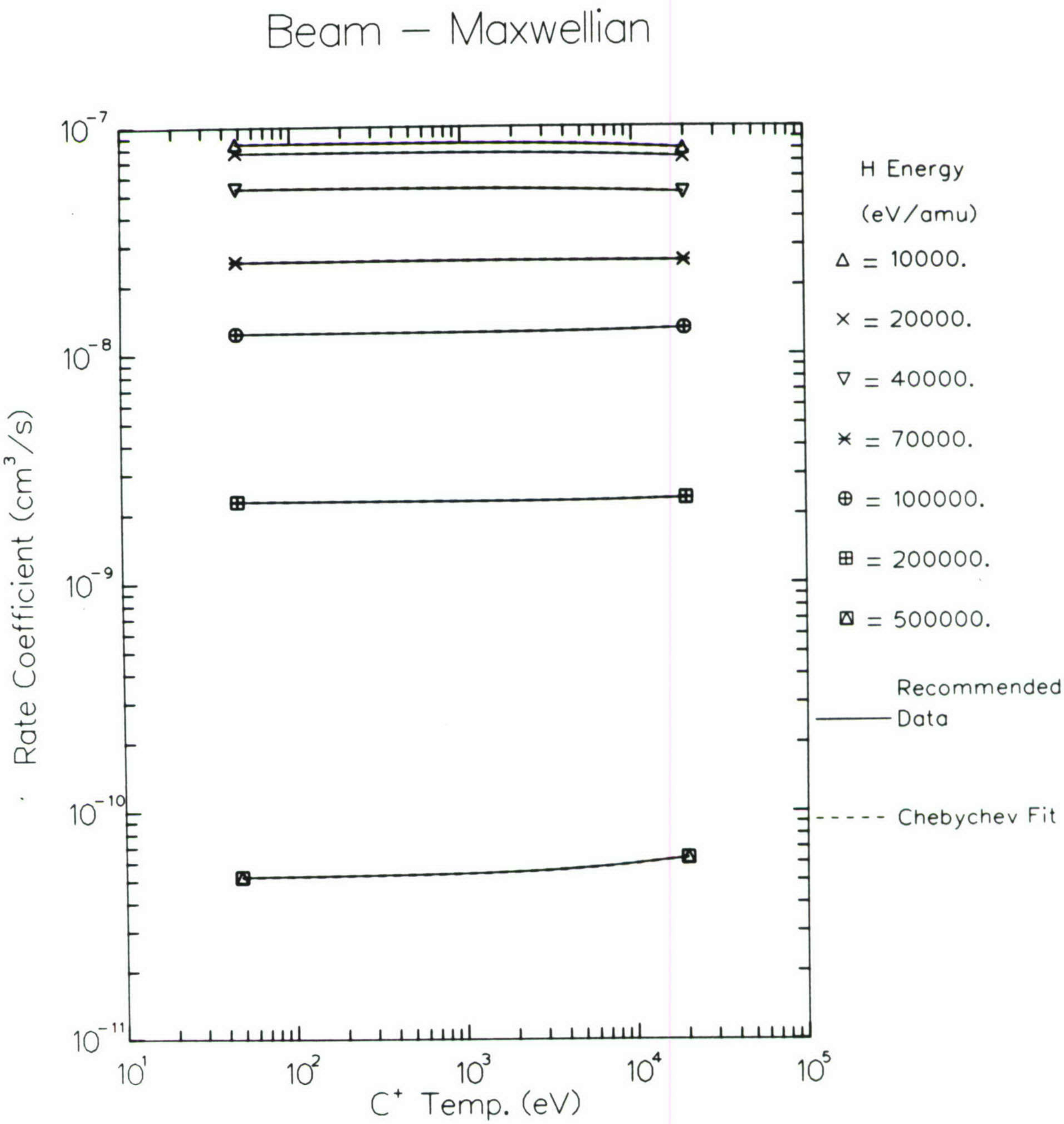
Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 4.8E+01 eV, E_{max} = 2.0E+04 eV

Chebychev Fitting Parameters for Rate Coefficients

H Energy (eV/amu)	C1	C2	C3	C4	C5	C6	C7
10000.	1.671E-07	-2.030E-09	-1.137E-09	-4.506E-10	-1.203E-10	-1.875E-11	-7.153E-12
20000.	1.514E-07	-1.675E-09	-8.382E-10	-3.146E-10	-1.060E-10	-4.163E-11	-6.262E-12
40000.	1.050E-07	-1.135E-09	-4.843E-10	-1.558E-10	-4.012E-11	-9.038E-12	-3.980E-12
70000.	5.105E-08	5.683E-11	4.722E-11	2.225E-11	6.933E-12	1.126E-12	-1.018E-12
100000.	2.503E-08	2.576E-10	1.319E-10	5.184E-11	1.569E-11	3.556E-12	1.452E-12
200000.	4.588E-09	2.805E-11	1.930E-11	9.365E-12	3.461E-12	9.255E-13	7.009E-14
500000.	1.111E-10	4.976E-12	1.913E-12	5.609E-13	1.436E-13	3.517E-14	8.428E-15

See appendix for Chebychev fit details.

$H + C^+ \rightarrow C + H^+$



Total Electron Capture Cross Sections for
$C^{2+} + H \rightarrow C^{+} + H^{+}$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
1.0E+00	1.39E+06	6.89E-19
2.0E+00	1.96E+06	5.07E-19
4.0E+00	2.78E+06	4.58E-19
7.0E+00	3.68E+06	8.85E-19
1.0E+01	4.39E+06	3.83E-18
2.0E+01	6.21E+06	3.24E-17
4.0E+01	8.79E+06	9.85E-17
7.0E+01	1.16E+07	1.79E-16
1.0E+02	1.39E+07	2.37E-16
2.0E+02	1.96E+07	3.69E-16
4.0E+02	2.78E+07	4.43E-16
7.0E+02	3.68E+07	4.47E-16
1.0E+03	4.39E+07	4.54E-16
2.0E+03	6.21E+07	6.30E-16
4.0E+03	8.79E+07	7.84E-16
7.0E+03	1.16E+08	8.32E-16
1.0E+04	1.39E+08	8.22E-16
2.0E+04	1.96E+08	7.26E-16
4.0E+04	2.78E+08	4.46E-16
7.0E+04	3.68E+08	1.41E-16
1.0E+05	4.39E+08	5.03E-17
2.0E+05	6.21E+08	7.84E-18

References: E.1, E.3, E.4, E.5, T.1, T.3, T.4, T.5

Accuracy: 30% for $1 \leq E(eV/amu) \leq 9$; 20% for $40 \leq E(eV/amu) \leq 2x10^5$

Notes: (1) In the region $9 < E(eV/amu) < 40$, the cross section has been interpolated with an estimated accuracy of 40%.

(2) For $E < 1$ eV/amu, the cross section continues to increase with decreasing energy, at least down to 0.2 eV/amu, retaining the same slope [T.3].

(3) For $E \leq 5$ eV/amu capture dominantly goes to the ground state $(2s^2\ 2p)^2P^0$ of C^+; for $6 \leq E(eV/amu) \leq 70$ the excited state $(2s2p^2)^2D$ of C^+ is dominantly populated [T.3]. If the C^{2+} ions are initially in the ground state, dominant population of $C^+(2s2p^2)^2D$ state continues at least up to ~ $2x10^2$ eV/amu [E.6].

(4) C^{2+} beams produced in plasma ion sources contain a significant fraction of metastable C^{2+} $(1s^22s2p)$ $^3P^0$ ions [E.6]. In the energy region ~ $2x10^2 \leq E(eV/amu) < 1x10^3$, capture by metastable ions goes predominantly to the $(2s^2\ 3p)^2P^0$ state of C^+.

For Chebychev fits of the above cross sections it is necessary to use the following parameters.
E_{min} = 1.0E+00 eV/amu, E_{max} = 2.0E+05 eV/amu

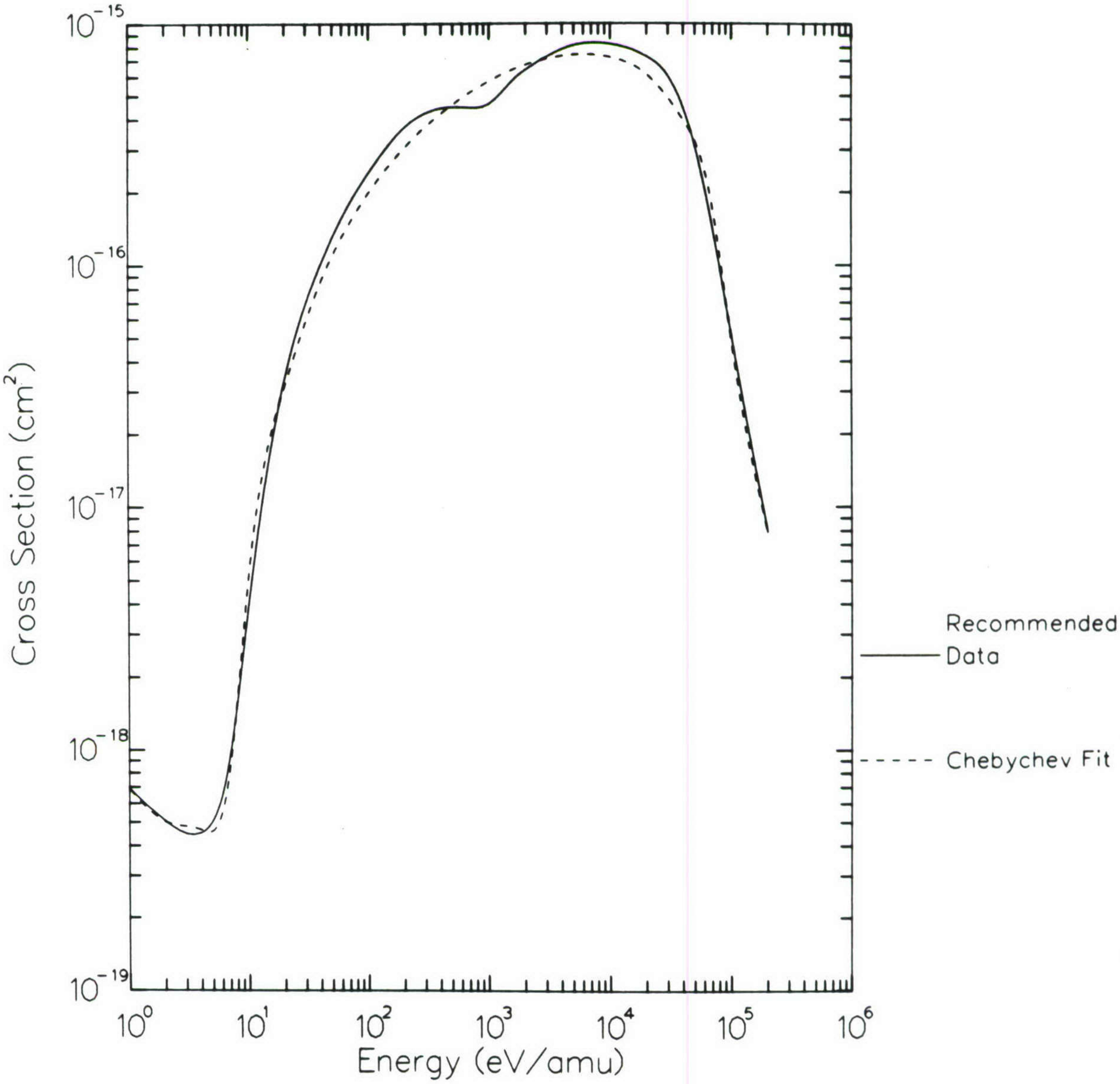
Chebychev Fitting Parameters for Cross Sections

C1	C2	C3	C4	C5	C6	C7	C8	C9
4.306E-16	1.417E-16	-2.570E-16	-2.299E-16	-3.362E-18	7.030E-17	3.955E-17	2.153E-17	9.815E-18

The fit represents the above cross sections with an rms deviation of 14.0%.
The maximum deviation is 30.2% at 1.0E+01 eV/amu.
See appendix for Chebychev fit details.

$C^{2+} + H \rightarrow C^{+} + H^{+}$

Cross Section vs. Energy



Total Electron Capture Rate Coefficients for
$C^{2+} + H \rightarrow C^{+} + H^{+}$

Maxwellian - Maxwellian Rate Coefficients (cm^3/s)

C^{2+} Temp. (eV)	Equal Temp.	H Temp. (eV) 1.	10.	100.	1000.	5000.	10000.	20000.
1.0E+00	1.06E-12	1.06E-12	1.85E-10	4.87E-09	2.91E-08	8.44E-08	1.07E-07	1.08E-07
1.2E+00	1.18E-12	1.07E-12	1.86E-10	4.87E-09	2.91E-08	8.44E-08	1.07E-07	1.08E-07
2.4E+00	4.66E-12	1.12E-12	1.90E-10	4.88E-09	2.91E-08	8.44E-08	1.07E-07	1.08E-07
4.8E+00	3.78E-11	1.26E-12	1.97E-10	4.89E-09	2.91E-08	8.44E-08	1.07E-07	1.08E-07
8.4E+00	1.49E-10	1.63E-12	2.09E-10	4.90E-09	2.91E-08	8.44E-08	1.07E-07	1.08E-07
1.2E+01	3.05E-10	2.28E-12	2.21E-10	4.91E-09	2.91E-08	8.44E-08	1.07E-07	1.08E-07
2.4E+01	9.65E-10	7.25E-12	2.62E-10	4.96E-09	2.91E-08	8.44E-08	1.07E-07	1.08E-07
4.8E+01	2.43E-09	3.39E-11	3.50E-10	5.05E-09	2.92E-08	8.44E-08	1.07E-07	1.08E-07
8.4E+01	4.45E-09	1.12E-10	4.93E-10	5.18E-09	2.92E-08	8.44E-08	1.07E-07	1.08E-07
1.2E+02	6.16E-09	2.21E-10	6.45E-10	5.32E-09	2.93E-08	8.45E-08	1.07E-07	1.08E-07
2.4E+02	1.05E-08	6.97E-10	1.19E-09	5.74E-09	2.95E-08	8.45E-08	1.07E-07	1.08E-07
4.8E+02	1.74E-08	1.81E-09	2.31E-09	6.55E-09	3.00E-08	8.47E-08	1.07E-07	1.08E-07
8.4E+02	2.70E-08	3.45E-09	3.91E-09	7.65E-09	3.07E-08	8.49E-08	1.07E-07	1.08E-07
1.2E+03	3.57E-08	4.91E-09	5.32E-09	8.65E-09	3.13E-08	8.52E-08	1.07E-07	1.08E-07
2.4E+03	5.85E-08	8.68E-09	8.96E-09	1.16E-08	3.35E-08	8.59E-08	1.07E-07	1.08E-07
4.8E+03	8.59E-08	1.43E-08	1.45E-08	1.69E-08	3.78E-08	8.74E-08	1.08E-07	1.08E-07
8.4E+03	1.05E-07	2.19E-08	2.21E-08	2.43E-08	4.37E-08	8.94E-08	1.08E-07	1.07E-07
1.2E+04	1.11E-07	2.91E-08	2.93E-08	3.13E-08	4.90E-08	9.14E-08	1.09E-07	1.07E-07
2.0E+04	1.06E-07	4.29E-08	4.31E-08	4.48E-08	5.93E-08	9.52E-08	1.10E-07	1.06E-07

Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

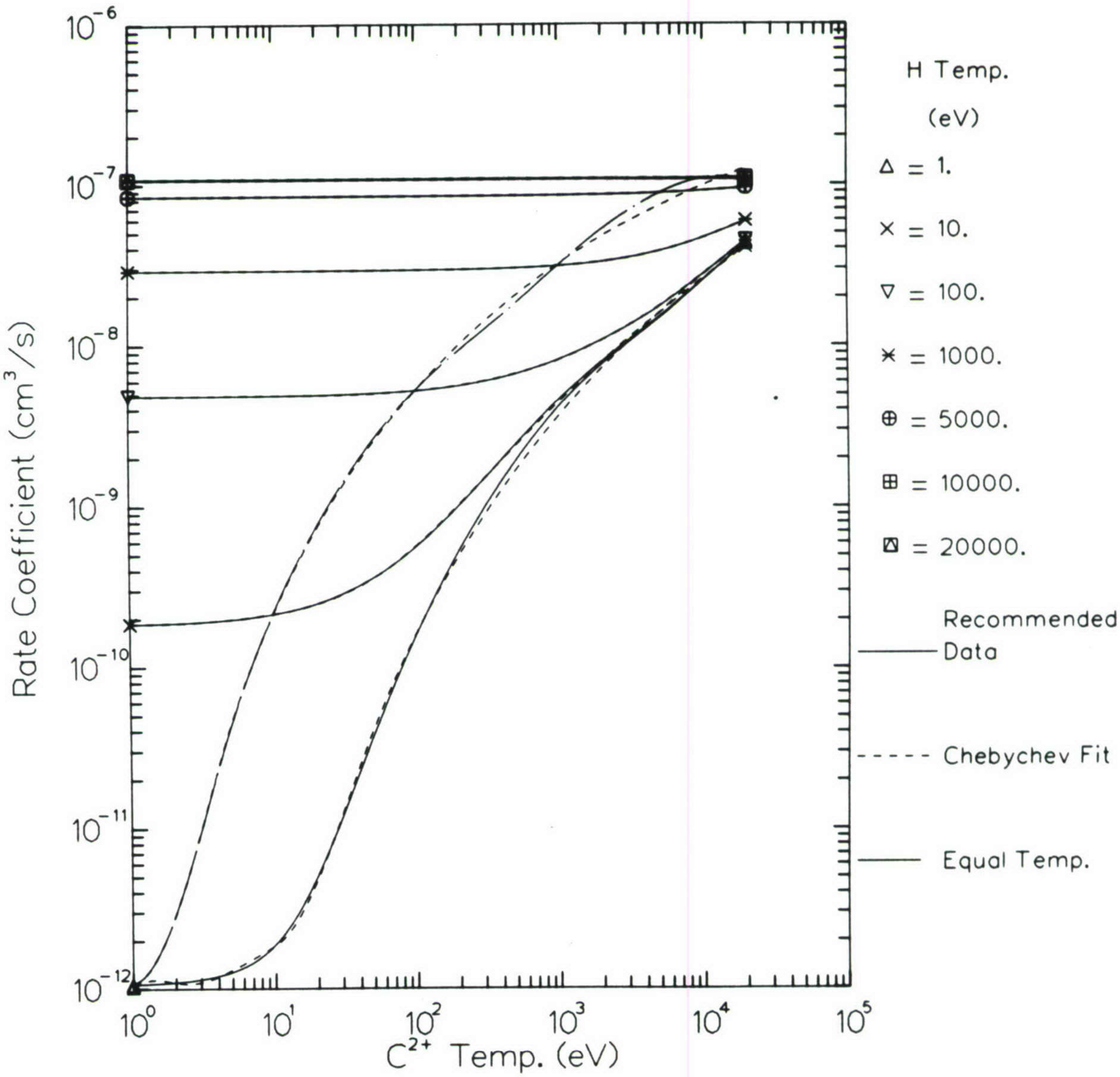
Chebychev Fitting Parameters for Rate Coefficients

H Temp. (eV)	C1	C2	C3	C4	C5	C6	C7
1.	1.880E-08	1.645E-08	1.095E-08	5.405E-09	1.878E-09	4.117E-10	4.271E-11
10.	1.821E-08	1.537E-08	9.792E-09	4.545E-09	1.463E-09	2.909E-10	2.694E-11
100.	2.592E-08	1.412E-08	9.472E-09	5.002E-09	2.134E-09	7.460E-10	2.020E-10
1000.	7.013E-08	1.060E-08	7.333E-09	4.009E-09	1.723E-09	5.580E-10	1.125E-10
5000.	1.730E-07	3.732E-09	2.596E-09	1.441E-09	6.389E-10	2.211E-10	5.629E-11
10000.	2.151E-07	9.453E-10	6.494E-10	3.486E-10	1.437E-10	4.196E-11	3.995E-12
20000.	2.153E-07	-5.792E-10	-4.184E-10	-2.516E-10	-1.284E-10	-5.545E-11	-2.203E-11
Equal Temp.	7.030E-08	5.622E-08	2.756E-08	6.592E-09	-4.521E-10	-6.799E-10	-1.239E-10

See appendix for Chebychev fit details.

$C^{2+} + H \rightarrow C^{+} + H^{+}$

Maxwellian – Maxwellian



Total Electron Capture Rate Coefficients for
$H + C^{2+} \rightarrow C^{+} + H^{+}$

Beam - Maxwellian Rate Coefficients (cm^3/s)

C^{2+} Temp. (eV)	H Energy (eV/amu) 10000.	20000.	40000.	70000.	100000.	200000.	500000.
1.0E+00	1.14E-07	1.43E-07	1.24E-07	5.18E-08	2.21E-08	4.87E-09	4.82E-10
1.2E+00	1.14E-07	1.43E-07	1.24E-07	5.18E-08	2.21E-08	4.87E-09	4.82E-10
2.4E+00	1.14E-07	1.43E-07	1.24E-07	5.18E-08	2.21E-08	4.87E-09	4.82E-10
4.8E+00	1.14E-07	1.43E-07	1.24E-07	5.18E-08	2.21E-08	4.87E-09	4.82E-10
8.4E+00	1.14E-07	1.43E-07	1.24E-07	5.18E-08	2.21E-08	4.87E-09	4.82E-10
1.2E+01	1.14E-07	1.43E-07	1.24E-07	5.18E-08	2.21E-08	4.87E-09	4.82E-10
2.4E+01	1.14E-07	1.42E-07	1.24E-07	5.18E-08	2.21E-08	4.87E-09	4.82E-10
4.8E+01	1.14E-07	1.42E-07	1.24E-07	5.18E-08	2.21E-08	4.87E-09	4.82E-10
8.4E+01	1.14E-07	1.42E-07	1.23E-07	5.19E-08	2.21E-08	4.87E-09	4.82E-10
1.2E+02	1.14E-07	1.42E-07	1.23E-07	5.19E-08	2.22E-08	4.86E-09	4.82E-10
2.4E+02	1.14E-07	1.42E-07	1.23E-07	5.19E-08	2.22E-08	4.86E-09	4.82E-10
4.8E+02	1.14E-07	1.42E-07	1.23E-07	5.19E-08	2.22E-08	4.86E-09	4.82E-10
8.4E+02	1.14E-07	1.42E-07	1.22E-07	5.20E-08	2.23E-08	4.86E-09	4.82E-10
1.2E+03	1.14E-07	1.41E-07	1.22E-07	5.20E-08	2.23E-08	4.86E-09	4.83E-10
2.4E+03	1.14E-07	1.40E-07	1.21E-07	5.22E-08	2.25E-08	4.86E-09	4.83E-10
4.8E+03	1.15E-07	1.40E-07	1.19E-07	5.24E-08	2.28E-08	4.87E-09	4.84E-10
8.4E+03	1.15E-07	1.38E-07	1.17E-07	5.27E-08	2.31E-08	4.88E-09	4.85E-10
1.2E+04	1.15E-07	1.37E-07	1.15E-07	5.30E-08	2.35E-08	4.90E-09	4.87E-10
2.0E+04	1.16E-07	1.34E-07	1.12E-07	5.35E-08	2.42E-08	4.95E-09	4.90E-10

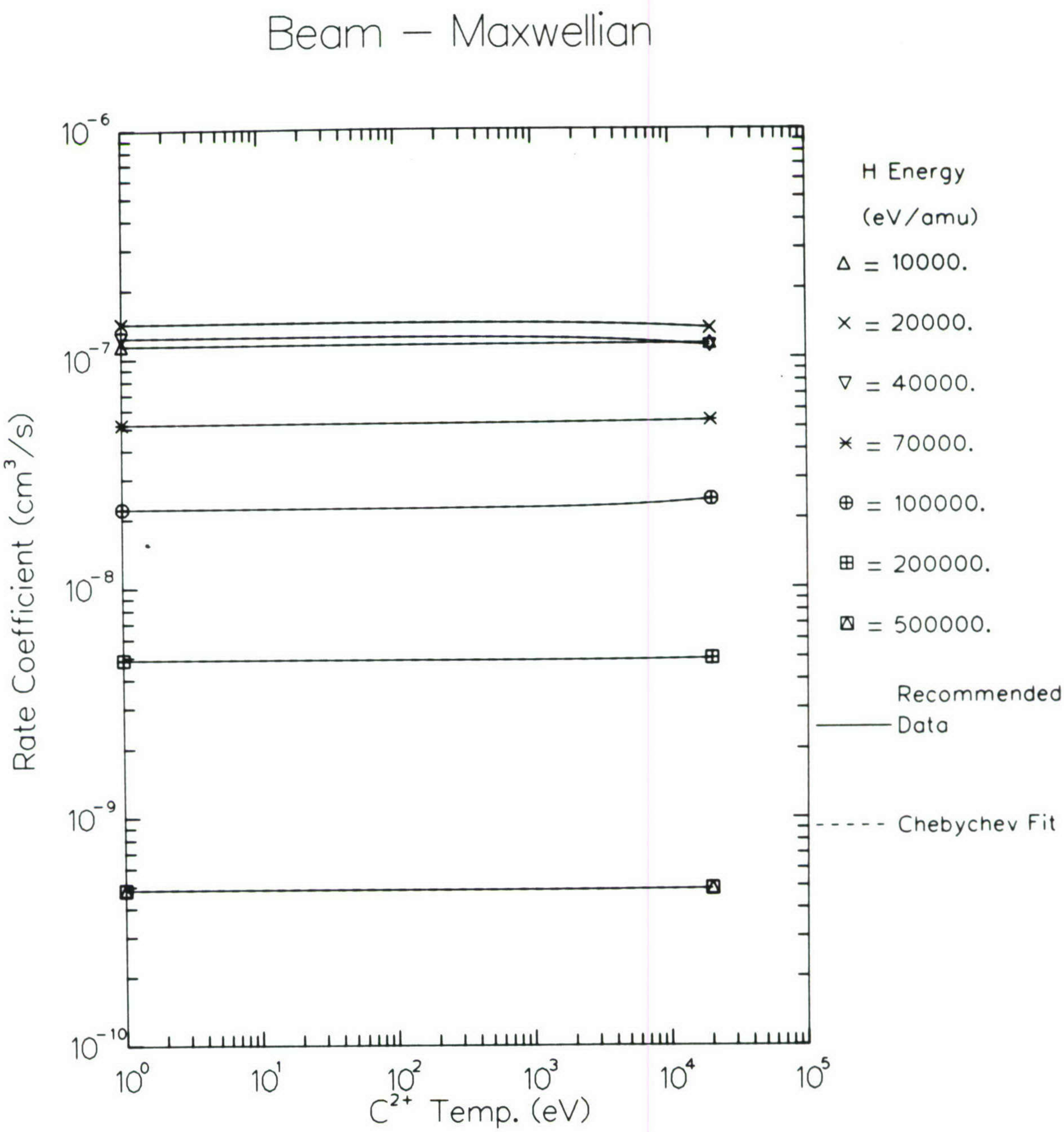
Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

Chebychev Fitting Parameters for Rate Coefficients

H Energy (eV/amu)	C1	C2	C3	C4	C5	C6	C7
10000.	2.290E-07	5.409E-10	4.085E-10	2.456E-10	1.025E-10	1.704E-11	-1.327E-11
20000.	2.813E-07	-3.214E-09	-1.926E-09	-9.284E-10	-3.866E-10	-1.476E-10	-5.764E-11
40000.	2.421E-07	-4.608E-09	-2.646E-09	-1.193E-09	-4.445E-10	-1.376E-10	-3.626E-11
70000.	1.044E-07	6.228E-10	3.921E-10	1.921E-10	7.247E-11	1.887E-11	2.741E-13
100000.	4.508E-08	7.515E-10	4.797E-10	2.511E-10	1.123E-10	4.289E-11	1.449E-11
200000.	9.754E-09	1.901E-11	2.074E-11	1.620E-11	9.561E-12	4.449E-12	1.686E-12
500000.	9.671E-10	2.705E-12	1.946E-12	1.171E-12	6.054E-13	2.720E-13	1.196E-13

See appendix for Chebychev fit details.

$H + C^{2+} \rightarrow C^{+} + H^{+}$



Total Electron Capture Cross Sections for
$C^{3+} + H \rightarrow C^{2+} + H^+$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
1.0E+00	1.39E+06	2.62E-15
2.0E+00	1.96E+06	2.05E-15
4.0E+00	2.78E+06	1.66E-15
7.0E+00	3.68E+06	1.41E-15
1.0E+01	4.39E+06	1.28E-15
2.0E+01	6.21E+06	1.01E-15
4.0E+01	8.79E+06	8.13E-16
7.0E+01	1.16E+07	6.84E-16
1.0E+02	1.39E+07	6.15E-16
2.0E+02	1.96E+07	5.20E-16
4.0E+02	2.78E+07	5.73E-16
7.0E+02	3.68E+07	7.41E-16
1.0E+03	4.39E+07	8.90E-16
2.0E+03	6.21E+07	1.37E-15
4.0E+03	8.79E+07	1.67E-15
7.0E+03	1.16E+08	1.79E-15
1.0E+04	1.39E+08	1.80E-15
2.0E+04	1.96E+08	1.61E-15
4.0E+04	2.78E+08	1.05E-15
7.0E+04	3.68E+08	4.00E-16
1.0E+05	4.39E+08	1.66E-16
2.0E+05	6.21E+08	1.72E-17
2.1E+05	6.29E+08	1.43E-17

References: E.1, E.3, E.5, E.7, E.8, T.1, T.6, T.7, T.8, T.9

Accuracy: 25% for $1 \leq E(eV/amu) \leq 2x10^5$

Notes: (1) Li-like ion beams are expected to contain only ions in the $1s^2 2s(^2S_{1/2})$ ground state.

(2) The cross section for energies below 1 eV/amu can be smoothly extrapolated (by retaining the same slope of the curve) to match the values $\sigma = 1.6x10^{-14}$ cm^2 (at $E = 5x10^{-3}$ eV/amu) and $\sigma = 3.5x10^{-14}$ cm^2 (at $E = 1x10^{-3}$ eV/amu) obtained in Ref. [T.10]. This behavior was taken into account in calculations of rate coefficients at low T.

(3) Both the theory [T.7] and experiment [E.6] show that for $E \leq 10^4$ eV/amu the excited product state C^{2+} $(2s3s)^3S$ is predominantly populated.

For Chebychev fits of the above cross sections it is necessary to use the following parameters.
E_{min} = 1.0E+00 eV/amu, E_{max} = 2.1E+05 eV/amu

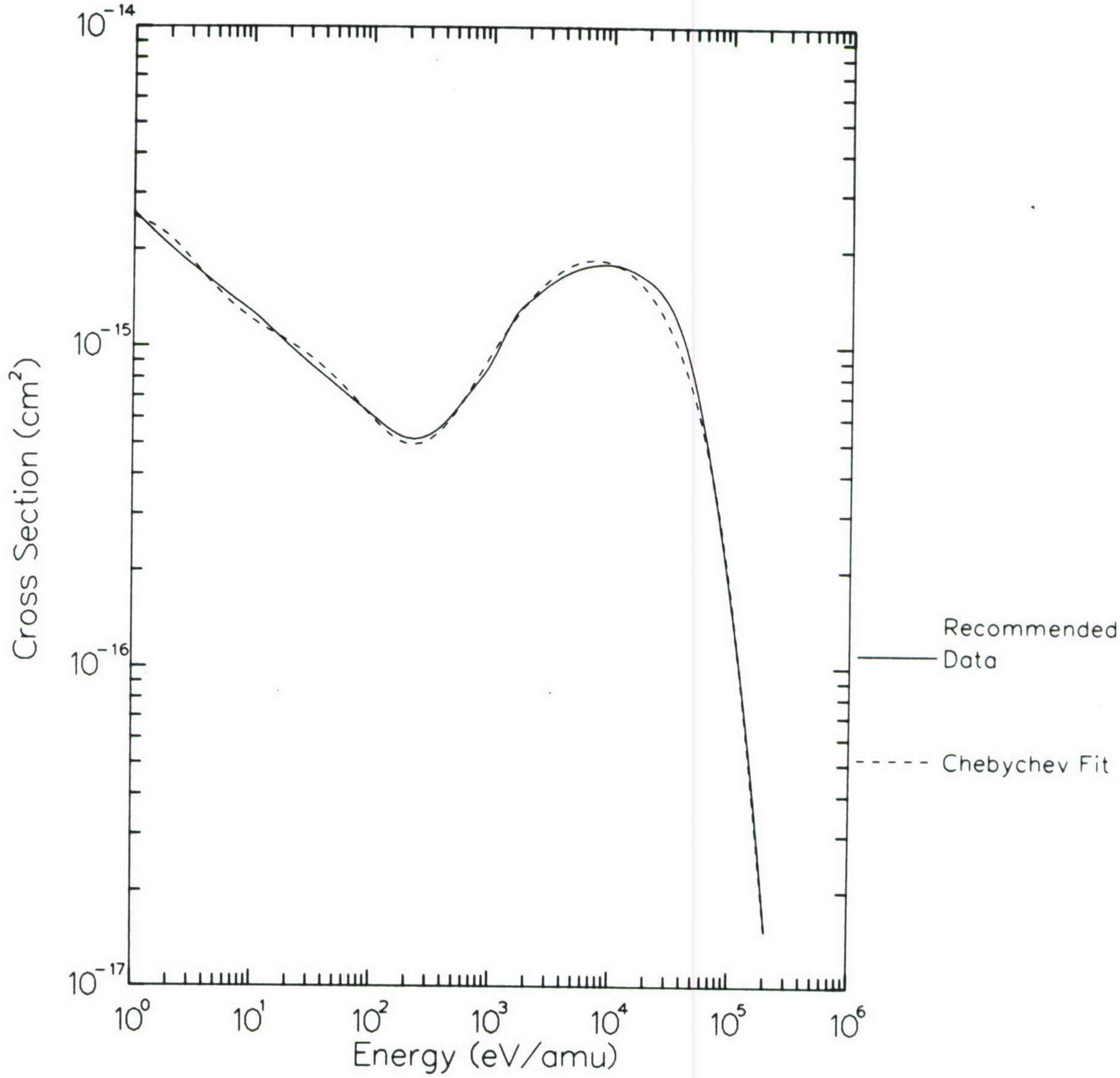
Chebychev Fitting Parameters for Cross Sections

C1	C2	C3	C4	C5	C6	C7	C8	C9
2.351E-15	-8.261E-16	1.433E-16	-6.892E-16	-1.429E-16	1.963E-16	1.992E-16	6.075E-17	-1.015E-16

The fit represents the above cross sections with an rms deviation of 5.7%.
The maximum deviation is 8.1% at 2.0E+00 eV/amu.
See appendix for Chebychev fit details.

$C^{3+} + H \rightarrow C^{2+} + H^{+}$

Cross Section vs. Energy



Total Electron Capture Rate Coefficients for
$C^{3+} + H \rightarrow C^{2+} + H^{+}$

Maxwellian - Maxwellian Rate Coefficients (cm^3/s)

C^{3+} Temp. (eV)	Equal Temp.	H Temp. (eV) 1.	10.	100.	1000.	5000.	10000.	20000.
1.0E+00	3.73E-09	3.73E-09	5.67E-09	9.56E-09	5.93E-08	1.83E-07	2.37E-07	2.48E-07
1.2E+00	3.85E-09	3.74E-09	5.68E-09	9.56E-09	5.93E-08	1.83E-07	2.37E-07	2.48E-07
2.4E+00	4.38E-09	3.80E-09	5.69E-09	9.57E-09	5.93E-08	1.83E-07	2.37E-07	2.48E-07
4.8E+00	5.01E-09	3.91E-09	5.71E-09	9.58E-09	5.93E-08	1.83E-07	2.37E-07	2.48E-07
8.4E+00	5.57E-09	4.05E-09	5.74E-09	9.59E-09	5.94E-08	1.83E-07	2.37E-07	2.48E-07
1.2E+01	5.95E-09	4.17E-09	5.77E-09	9.60E-09	5.94E-08	1.83E-07	2.37E-07	2.48E-07
2.4E+01	6.77E-09	4.51E-09	5.86E-09	9.64E-09	5.94E-08	1.83E-07	2.37E-07	2.48E-07
4.8E+01	7.82E-09	4.97E-09	6.03E-09	9.71E-09	5.95E-08	1.83E-07	2.37E-07	2.48E-07
8.4E+01	9.22E-09	5.44E-09	6.25E-09	9.83E-09	5.97E-08	1.84E-07	2.37E-07	2.48E-07
1.2E+02	1.08E-08	5.77E-09	6.44E-09	9.95E-09	5.98E-08	1.84E-07	2.37E-07	2.48E-07
2.4E+02	1.71E-08	6.50E-09	6.96E-09	1.04E-08	6.04E-08	1.84E-07	2.38E-07	2.47E-07
4.8E+02	3.22E-08	7.41E-09	7.75E-09	1.12E-08	6.14E-08	1.84E-07	2.38E-07	2.47E-07
8.4E+02	5.45E-08	8.49E-09	8.82E-09	1.25E-08	6.30E-08	1.85E-07	2.38E-07	2.47E-07
1.2E+03	7.43E-08	9.60E-09	9.95E-09	1.40E-08	6.45E-08	1.85E-07	2.38E-07	2.47E-07
2.4E+03	1.25E-07	1.40E-08	1.45E-08	1.93E-08	6.95E-08	1.87E-07	2.38E-07	2.47E-07
4.8E+03	1.87E-07	2.51E-08	2.56E-08	3.10E-08	7.90E-08	1.90E-07	2.40E-07	2.47E-07
8.4E+03	2.32E-07	4.28E-08	4.33E-08	4.85E-08	9.21E-08	1.95E-07	2.41E-07	2.46E-07
1.2E+04	2.48E-07	5.94E-08	5.98E-08	6.45E-08	1.04E-07	2.00E-07	2.42E-07	2.46E-07
2.0E+04	2.45E-07	9.05E-08	9.09E-08	9.46E-08	1.27E-07	2.08E-07	2.45E-07	2.45E-07

Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

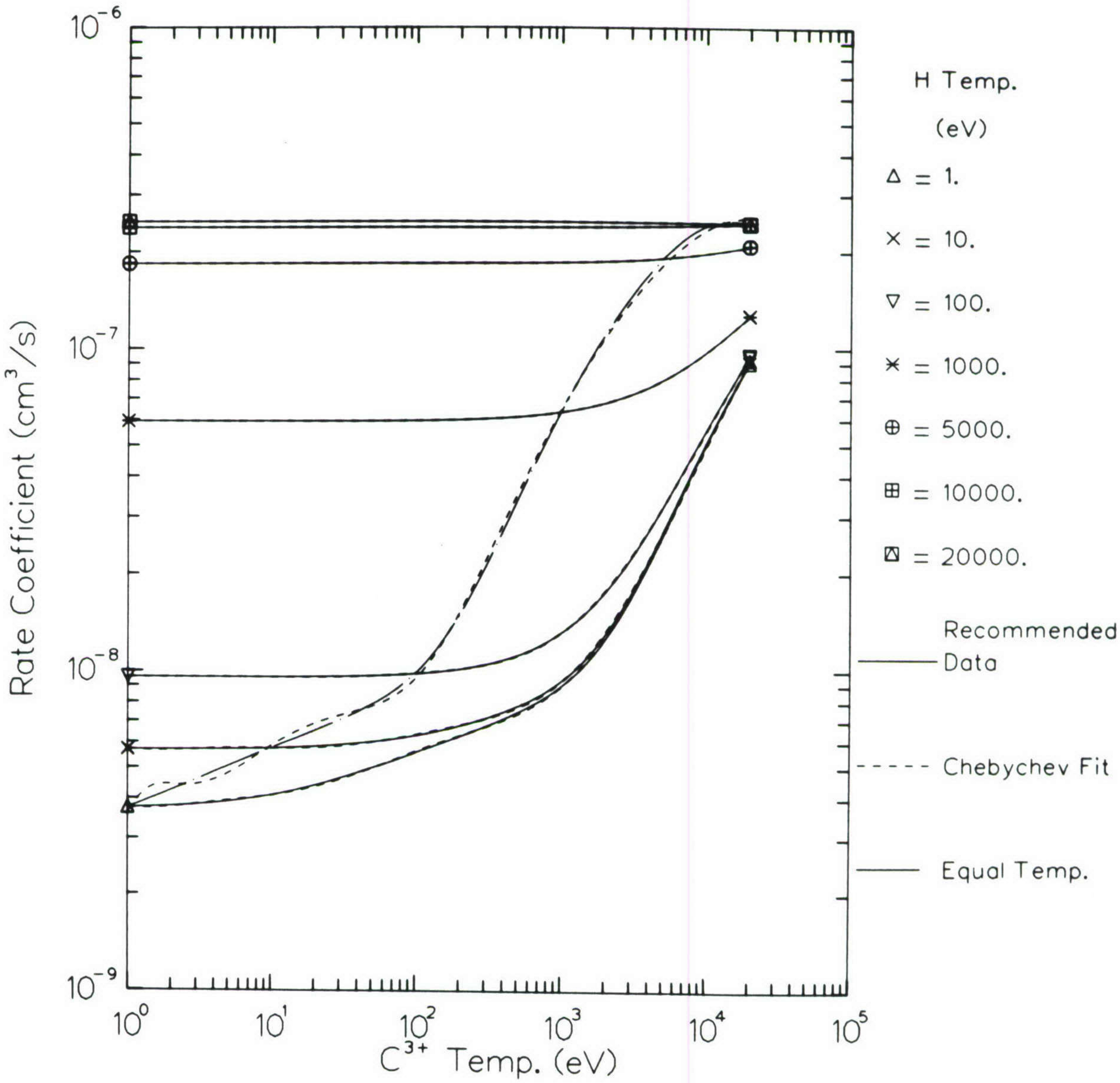
Chebychev Fitting Parameters for Rate Coefficients

H Temp. (eV)	C1	C2	C3	C4	C5	C6	C7
1.	4.130E-08	2.949E-08	2.050E-08	1.238E-08	6.411E-09	2.510E-09	5.769E-10
10.	4.335E-08	2.863E-08	2.075E-08	1.251E-08	6.258E-09	2.427E-09	5.878E-10
100.	5.142E-08	2.894E-08	2.089E-08	1.220E-08	5.671E-09	1.983E-09	4.246E-10
1000.	1.456E-07	2.377E-08	1.640E-08	8.927E-09	3.810E-09	1.220E-09	2.405E-10
5000.	3.766E-07	8.640E-09	6.022E-09	3.346E-09	1.482E-09	5.070E-10	1.165E-10
10000.	4.777E-07	2.580E-09	1.787E-09	9.780E-10	4.202E-10	1.351E-10	2.438E-11
20000.	4.940E-07	-9.458E-10	-6.871E-10	-4.184E-10	-2.176E-10	-9.647E-11	-3.992E-11
Equal Temp.	1.610E-07	1.237E-07	6.240E-08	1.216E-08	-9.906E-09	-9.776E-09	-3.334E-09

See appendix for Chebychev fit details.

$C^{3+} + H \rightarrow C^{2+} + H^{+}$

Maxwellian — Maxwellian



Total Electron Capture Rate Coefficients for
$H + C^{3+} \rightarrow C^{2+} + H^{+}$

Beam - Maxwellian Rate Coefficients (cm^3/s)

C^{3+} Temp. (eV)	H Energy (eV/amu) 10000.	20000.	40000.	70000.	100000.	200000.	500000.
1.0E+00	2.50E-07	3.16E-07	2.92E-07	1.47E-07	7.29E-08	1.07E-08	1.06E-10
1.2E+00	2.50E-07	3.16E-07	2.92E-07	1.47E-07	7.29E-08	1.07E-08	1.06E-10
2.4E+00	2.50E-07	3.16E-07	2.92E-07	1.47E-07	7.29E-08	1.07E-08	1.06E-10
4.8E+00	2.50E-07	3.16E-07	2.92E-07	1.47E-07	7.29E-08	1.07E-08	1.06E-10
8.4E+00	2.50E-07	3.16E-07	2.91E-07	1.47E-07	7.29E-08	1.06E-08	1.06E-10
1.2E+01	2.50E-07	3.16E-07	2.91E-07	1.47E-07	7.29E-08	1.06E-08	1.06E-10
2.4E+01	2.50E-07	3.16E-07	2.91E-07	1.47E-07	7.29E-08	1.06E-08	1.06E-10
4.8E+01	2.50E-07	3.16E-07	2.91E-07	1.47E-07	7.29E-08	1.06E-08	1.06E-10
8.4E+01	2.50E-07	3.16E-07	2.91E-07	1.47E-07	7.29E-08	1.06E-08	1.06E-10
1.2E+02	2.50E-07	3.16E-07	2.91E-07	1.47E-07	7.29E-08	1.05E-08	1.06E-10
2.4E+02	2.50E-07	3.16E-07	2.90E-07	1.47E-07	7.30E-08	1.05E-08	1.06E-10
4.8E+02	2.50E-07	3.15E-07	2.89E-07	1.47E-07	7.30E-08	1.04E-08	1.06E-10
8.4E+02	2.50E-07	3.15E-07	2.88E-07	1.47E-07	7.31E-08	1.04E-08	1.06E-10
1.2E+03	2.50E-07	3.14E-07	2.88E-07	1.47E-07	7.31E-08	1.03E-08	1.07E-10
2.4E+03	2.50E-07	3.13E-07	2.86E-07	1.47E-07	7.32E-08	1.02E-08	1.07E-10
4.8E+03	2.51E-07	3.11E-07	2.82E-07	1.47E-07	7.36E-08	1.02E-08	1.08E-10
8.4E+03	2.52E-07	3.08E-07	2.78E-07	1.48E-07	7.41E-08	1.02E-08	1.08E-10
1.2E+04	2.53E-07	3.06E-07	2.74E-07	1.48E-07	7.46E-08	1.03E-08	1.10E-10
2.0E+04	2.55E-07	3.01E-07	2.67E-07	1.48E-07	7.57E-08	1.04E-08	1.12E-10

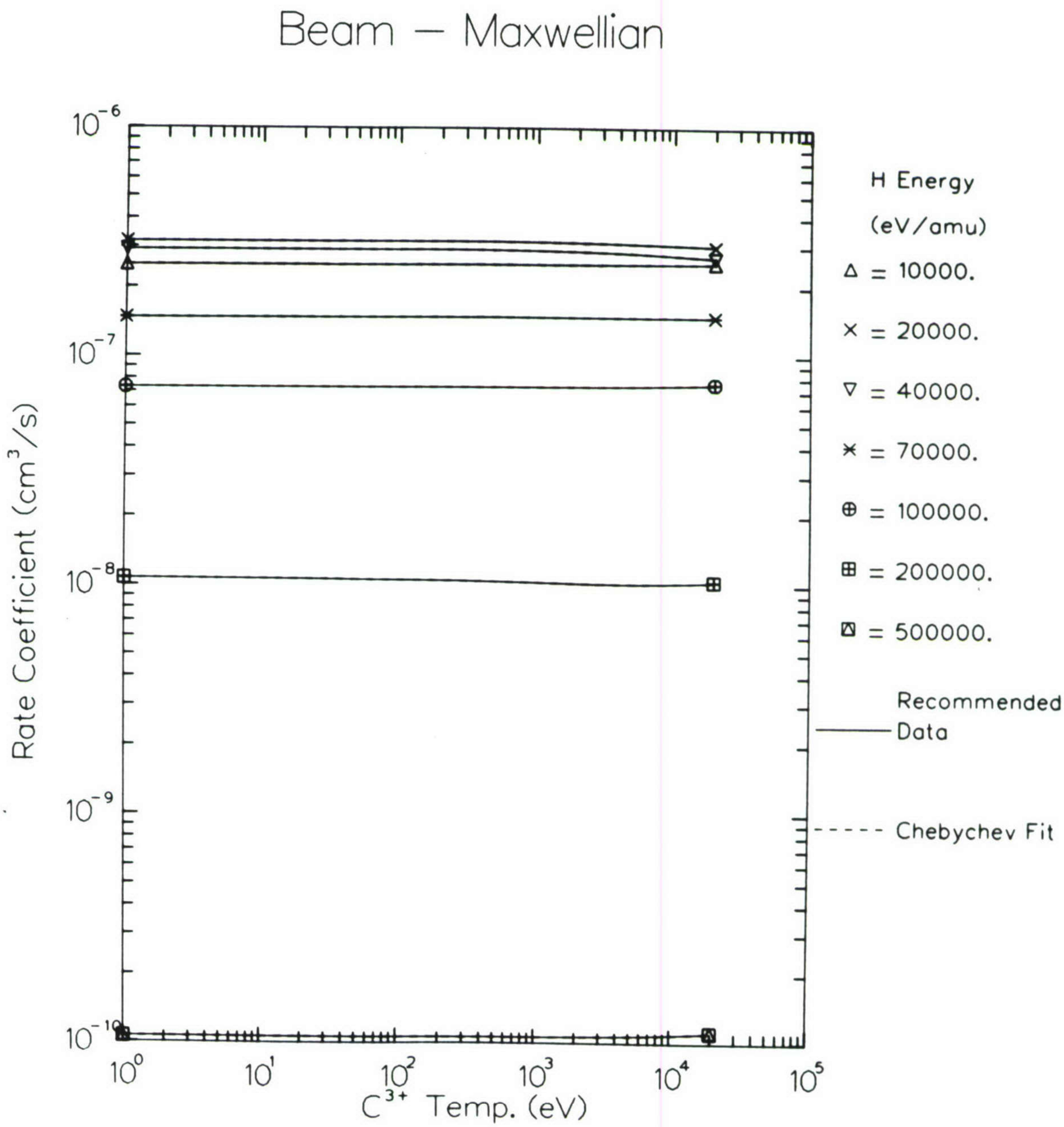
Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

Chebychev Fitting Parameters for Rate Coefficients

H Energy (eV/amu)	C1	C2	C3	C4	C5	C6	C7
10000.	5.016E-07	1.427E-09	1.172E-09	7.533E-10	3.475E-10	9.263E-11	-6.517E-12
20000.	6.257E-07	-5.715E-09	-3.510E-09	-1.740E-09	-7.437E-10	-2.904E-10	-1.142E-10
40000.	5.719E-07	-9.329E-09	-5.461E-09	-2.529E-09	-9.708E-10	-3.088E-10	-8.237E-11
70000.	2.945E-07	3.728E-10	1.932E-10	5.665E-11	-6.616E-12	-2.026E-11	-1.839E-11
100000.	1.469E-07	9.164E-10	6.459E-10	3.737E-10	1.804E-10	7.189E-11	2.407E-11
200000.	2.096E-08	-2.243E-10	2.688E-12	8.126E-11	6.233E-11	2.841E-11	9.692E-12
500000.	2.145E-10	1.826E-12	1.317E-12	7.916E-13	4.047E-13	1.764E-13	7.170E-14

See appendix for Chebychev fit details.

$H + C^{3+} \rightarrow C^{2+} + H^+$



Total Electron Capture Cross Sections for
$C^{4+} + H \rightarrow C^{3+} + H^+$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
1.0E+00	1.39E+06	1.53E-15
2.0E+00	1.96E+06	1.07E-15
4.0E+00	2.78E+06	8.58E-16
7.0E+00	3.68E+06	7.86E-16
1.0E+01	4.39E+06	8.80E-16
2.0E+01	6.21E+06	1.38E-15
4.0E+01	8.79E+06	1.94E-15
7.0E+01	1.16E+07	2.35E-15
1.0E+02	1.39E+07	2.58E-15
2.0E+02	1.96E+07	3.04E-15
4.0E+02	2.78E+07	3.36E-15
7.0E+02	3.68E+07	3.43E-15
1.0E+03	4.39E+07	3.43E-15
1.7E+03	5.66E+07	3.42E-15
2.0E+03	6.21E+07	3.40E-15
4.0E+03	8.79E+07	3.21E-15
7.0E+03	1.16E+08	3.11E-15
1.0E+04	1.39E+08	2.90E-15
2.0E+04	1.96E+08	2.48E-15
4.0E+04	2.78E+08	1.75E-15
7.0E+04	3.68E+08	7.50E-16
1.0E+05	4.39E+08	2.79E-16
2.0E+05	6.21E+08	2.46E-17
4.0E+05	8.78E+08	9.99E-19

References: E.1, E.3, E.5, E.7, E.8, E.9, E.10, T.1, T.8, T.9, T.11, T.12, T.13, T.14, T.15, T.16

Accuracy: 30% for $1 \leq E$(eV/amu) < 15; 20% for $15 \leq E$(eV/amu) < 1.8×10^5; 30-50% for E > 2×10^5 eV/amu

Notes: (1) In the region below 1 eV/amu, the cross section can be smoothly extrapolated to the value of $\sigma = 2 \times 10^{-14}$ cm^2 at $E = 10^{-2}$ eV/amu [T.11].

(2) The most populated final state in this reaction is: 3d for $E \lesssim 10$ eV/amu [T.11]; 3p for $10 < E$ (eV/amu) $\lesssim 1.5 \times 10^3$; 3s for $1.5 \times 10^3 <$ E(eV/amu) $\lesssim 4 \times 10^3$; and again 3d for $4 \times 10^3 <$ E(eV/amu) $\lesssim 1 \times 10^4$ [E.10], [T.14].

(3) In the energy region below 1×10^4 eV/amu, electron capture into the n=3 shell is more probable than capture into the n=4 shell by a factor of 5 or more.

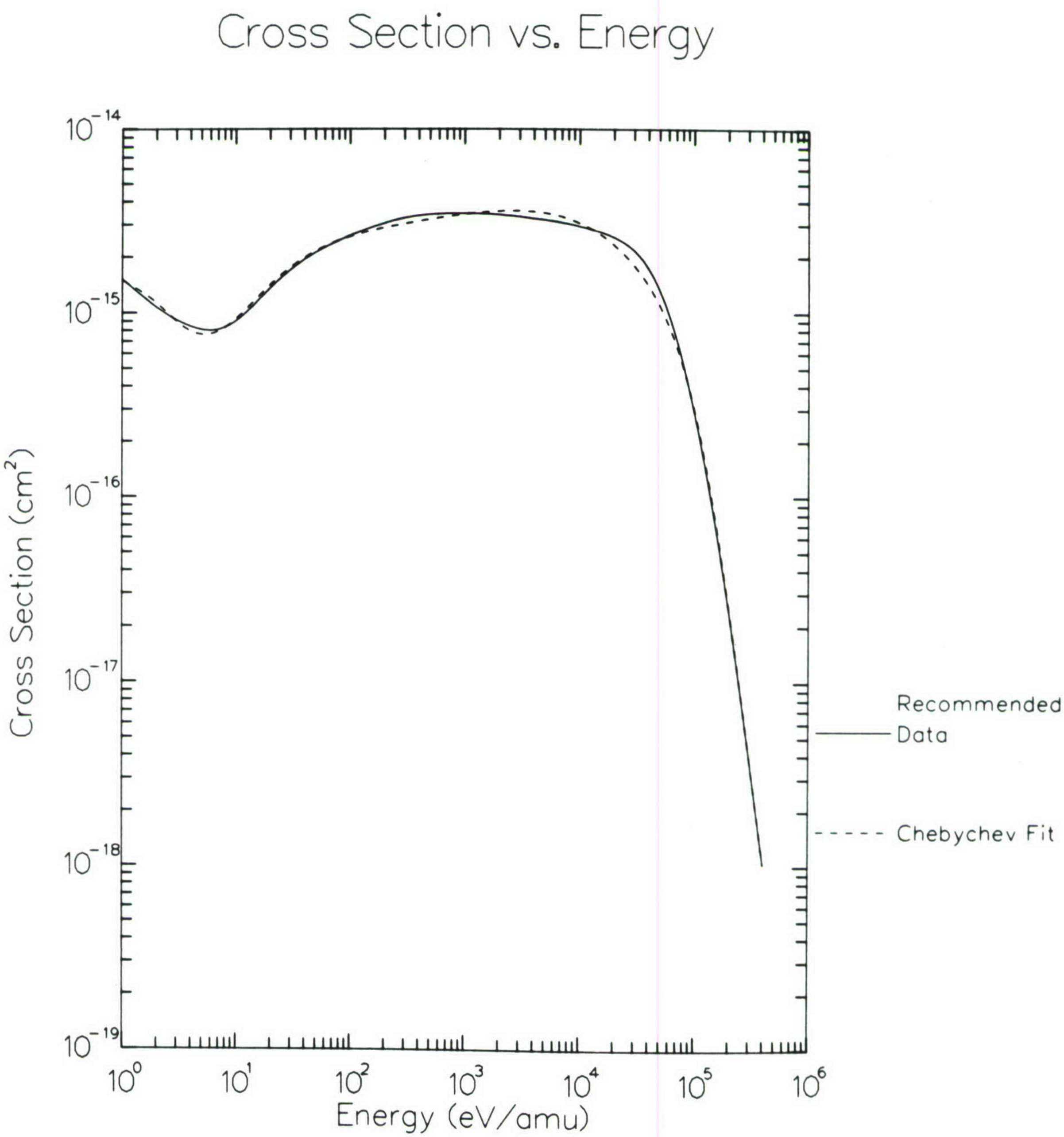
For Chebychev fits of the above cross sections it is necessary to use the following parameters.
E_{min} = 1.0E+00 eV/amu, E_{max} = 4.0E+05 eV/amu

Chebychev Fitting Parameters for Cross Sections

C1	C2	C3	C4	C5	C6	C7	C8	C9
3.098E-15	-3.722E-16	-1.356E-15	-5.709E-16	6.051E-16	1.783E-16	9.423E-17	2.677E-17	-1.528E-16

The fit represents the above cross sections with an rms deviation of 7.7%.
The maximum deviation is 12.6% at 1.0E+05 eV/amu.
See appendix for Chebychev fit details.

$C^{4+} + H \rightarrow C^{3+} + H^{+}$



Total Electron Capture Rate Coefficients for
$C^{4+} + H \rightarrow C^{3+} + H^+$

Maxwellian - Maxwellian Rate Coefficients (cm^3/s)

C^{4+} Temp. (eV)	Equal Temp.	H Temp. (eV) 1.	10.	100.	1000.	5000.	10000.	20000.
1.0E+00	2.17E-09	2.17E-09	6.50E-09	4.42E-08	1.66E-07	3.26E-07	3.93E-07	4.07E-07
1.2E+00	2.20E-09	2.18E-09	6.51E-09	4.42E-08	1.66E-07	3.26E-07	3.93E-07	4.07E-07
2.4E+00	2.52E-09	2.19E-09	6.57E-09	4.42E-08	1.66E-07	3.26E-07	3.93E-07	4.07E-07
4.8E+00	3.67E-09	2.22E-09	6.69E-09	4.42E-08	1.66E-07	3.26E-07	3.93E-07	4.07E-07
8.4E+00	5.91E-09	2.28E-09	6.87E-09	4.43E-08	1.66E-07	3.26E-07	3.93E-07	4.07E-07
1.2E+01	8.24E-09	2.35E-09	7.05E-09	4.44E-08	1.66E-07	3.26E-07	3.93E-07	4.07E-07
2.4E+01	1.54E-08	2.66E-09	7.65E-09	4.47E-08	1.66E-07	3.26E-07	3.93E-07	4.07E-07
4.8E+01	2.72E-08	3.57E-09	8.83E-09	4.54E-08	1.66E-07	3.26E-07	3.93E-07	4.07E-07
8.4E+01	4.13E-08	5.26E-09	1.06E-08	4.63E-08	1.66E-07	3.26E-07	3.93E-07	4.07E-07
1.2E+02	5.28E-08	7.05E-09	1.22E-08	4.71E-08	1.67E-07	3.26E-07	3.93E-07	4.07E-07
2.4E+02	8.15E-08	1.28E-08	1.74E-08	5.00E-08	1.67E-07	3.26E-07	3.94E-07	4.07E-07
4.8E+02	1.20E-07	2.25E-08	2.64E-08	5.55E-08	1.69E-07	3.27E-07	3.94E-07	4.07E-07
8.4E+02	1.59E-07	3.45E-08	3.76E-08	6.29E-08	1.71E-07	3.27E-07	3.94E-07	4.06E-07
1.2E+03	1.88E-07	4.44E-08	4.71E-08	6.96E-08	1.74E-07	3.28E-07	3.94E-07	4.06E-07
2.4E+03	2.54E-07	6.99E-08	7.18E-08	8.86E-08	1.81E-07	3.30E-07	3.95E-07	4.06E-07
4.8E+03	3.30E-07	1.04E-07	1.05E-07	1.17E-07	1.94E-07	3.34E-07	3.96E-07	4.06E-07
8.4E+03	3.86E-07	1.39E-07	1.40E-07	1.49E-07	2.12E-07	3.40E-07	3.98E-07	4.05E-07
1.2E+04	4.08E-07	1.66E-07	1.67E-07	1.74E-07	2.27E-07	3.46E-07	4.00E-07	4.04E-07
2.0E+04	4.02E-07	2.10E-07	2.10E-07	2.15E-07	2.57E-07	3.56E-07	4.03E-07	4.02E-07

Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

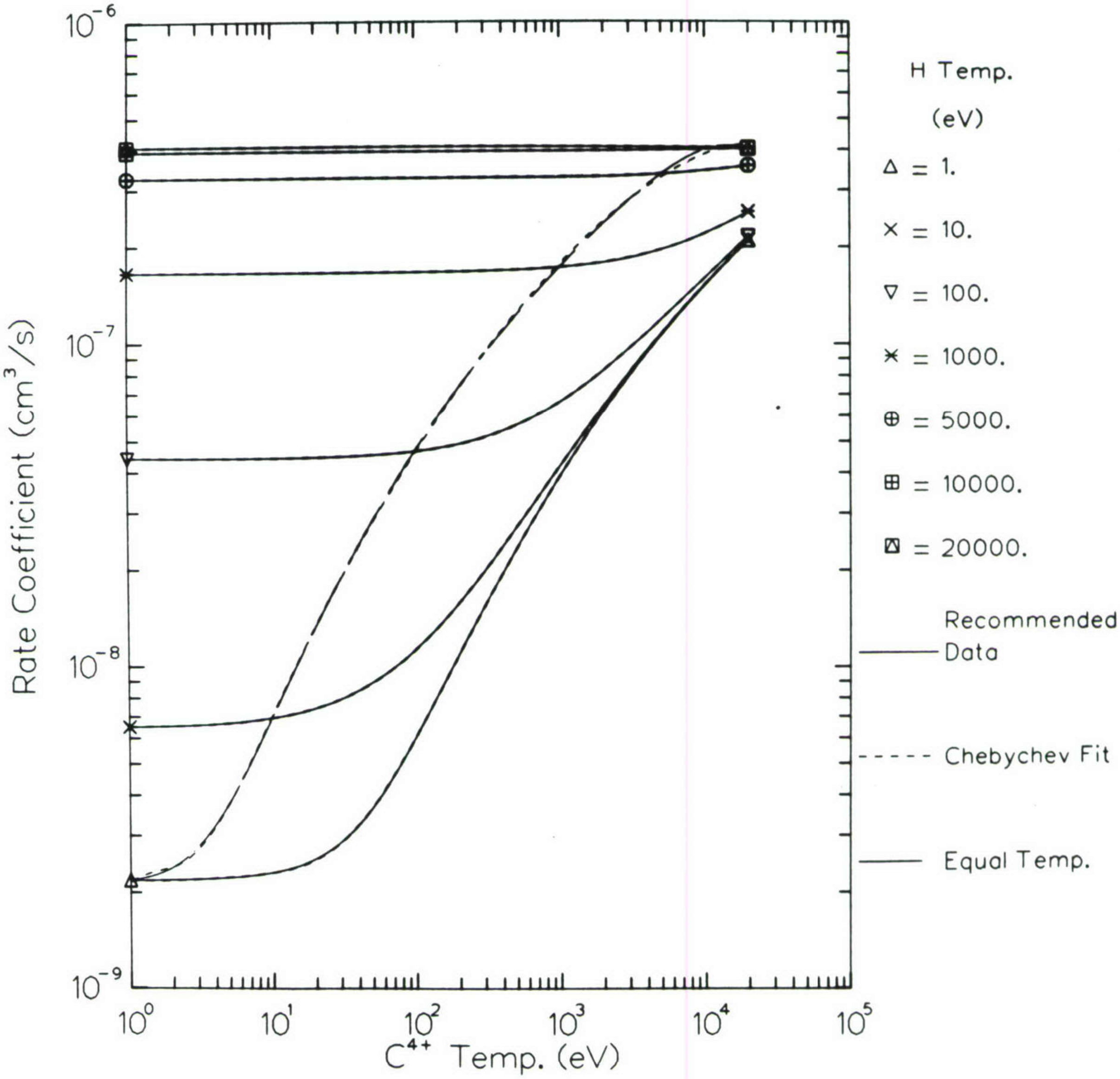
Chebychev Fitting Parameters for Rate Coefficients

H Temp. (eV)	C1	C2	C3	C4	C5	C6	C7
1.	1.093E-07	8.722E-08	4.886E-08	1.663E-08	2.058E-09	-6.684E-10	-2.222E-10
10.	1.159E-07	8.521E-08	4.780E-08	1.699E-08	2.698E-09	-5.413E-10	-3.152E-10
100.	1.687E-07	6.814E-08	4.141E-08	1.740E-08	4.330E-09	8.901E-11	-3.471E-10
1000.	3.688E-07	3.249E-08	2.205E-08	1.161E-08	4.656E-09	1.318E-09	1.596E-10
5000.	6.632E-07	1.060E-08	7.396E-09	4.117E-09	1.829E-09	6.288E-10	1.460E-10
10000.	7.906E-07	3.429E-09	2.379E-09	1.307E-09	5.661E-10	1.852E-10	3.607E-11
20000.	8.117E-07	-1.405E-09	-1.022E-09	-6.233E-10	-3.249E-10	-1.445E-10	-6.007E-11
Equal Temp.	2.958E-07	2.158E-07	7.695E-08	-2.272E-09	-1.431E-08	-6.591E-09	-1.458E-09

See appendix for Chebychev fit details.

$C^{4+} + H \rightarrow C^{3+} + H^{+}$

Maxwellian — Maxwellian



Total Electron Capture Rate Coefficients for
$H + C^{4+} \rightarrow C^{3+} + H^{+}$

Beam - Maxwellian Rate Coefficients (cm^3/s)

C^{4+} Temp. (eV)	H Energy (eV/amu) 10000.	20000.	40000.	70000.	100000.	200000.	500000.
1.0E+00	4.03E-07	4.87E-07	4.86E-07	2.76E-07	1.23E-07	1.53E-08	3.55E-10
1.2E+00	4.03E-07	4.87E-07	4.86E-07	2.76E-07	1.23E-07	1.53E-08	3.55E-10
2.4E+00	4.03E-07	4.87E-07	4.86E-07	2.76E-07	1.23E-07	1.53E-08	3.55E-10
4.8E+00	4.03E-07	4.87E-07	4.86E-07	2.76E-07	1.23E-07	1.53E-08	3.55E-10
8.4E+00	4.03E-07	4.87E-07	4.86E-07	2.75E-07	1.23E-07	1.53E-08	3.55E-10
1.2E+01	4.03E-07	4.87E-07	4.86E-07	2.75E-07	1.23E-07	1.53E-08	3.55E-10
2.4E+01	4.03E-07	4.87E-07	4.85E-07	2.75E-07	1.23E-07	1.53E-08	3.55E-10
4.8E+01	4.03E-07	4.87E-07	4.85E-07	2.75E-07	1.23E-07	1.53E-08	3.55E-10
8.4E+01	4.03E-07	4.87E-07	4.85E-07	2.75E-07	1.23E-07	1.53E-08	3.55E-10
1.2E+02	4.03E-07	4.86E-07	4.84E-07	2.75E-07	1.23E-07	1.53E-08	3.55E-10
2.4E+02	4.03E-07	4.86E-07	4.83E-07	2.75E-07	1.23E-07	1.53E-08	3.55E-10
4.8E+02	4.04E-07	4.85E-07	4.82E-07	2.74E-07	1.23E-07	1.53E-08	3.55E-10
8.4E+02	4.04E-07	4.85E-07	4.80E-07	2.74E-07	1.23E-07	1.53E-08	3.56E-10
1.2E+03	4.03E-07	4.85E-07	4.79E-07	2.74E-07	1.24E-07	1.53E-08	3.56E-10
2.4E+03	4.04E-07	4.83E-07	4.76E-07	2.73E-07	1.24E-07	1.54E-08	3.57E-10
4.8E+03	4.05E-07	4.81E-07	4.70E-07	2.72E-07	1.25E-07	1.55E-08	3.59E-10
8.4E+03	4.06E-07	4.79E-07	4.63E-07	2.70E-07	1.27E-07	1.57E-08	3.62E-10
1.2E+04	4.08E-07	4.76E-07	4.57E-07	2.69E-07	1.28E-07	1.59E-08	3.65E-10
2.0E+04	4.11E-07	4.73E-07	4.46E-07	2.66E-07	1.31E-07	1.64E-08	3.73E-10

Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

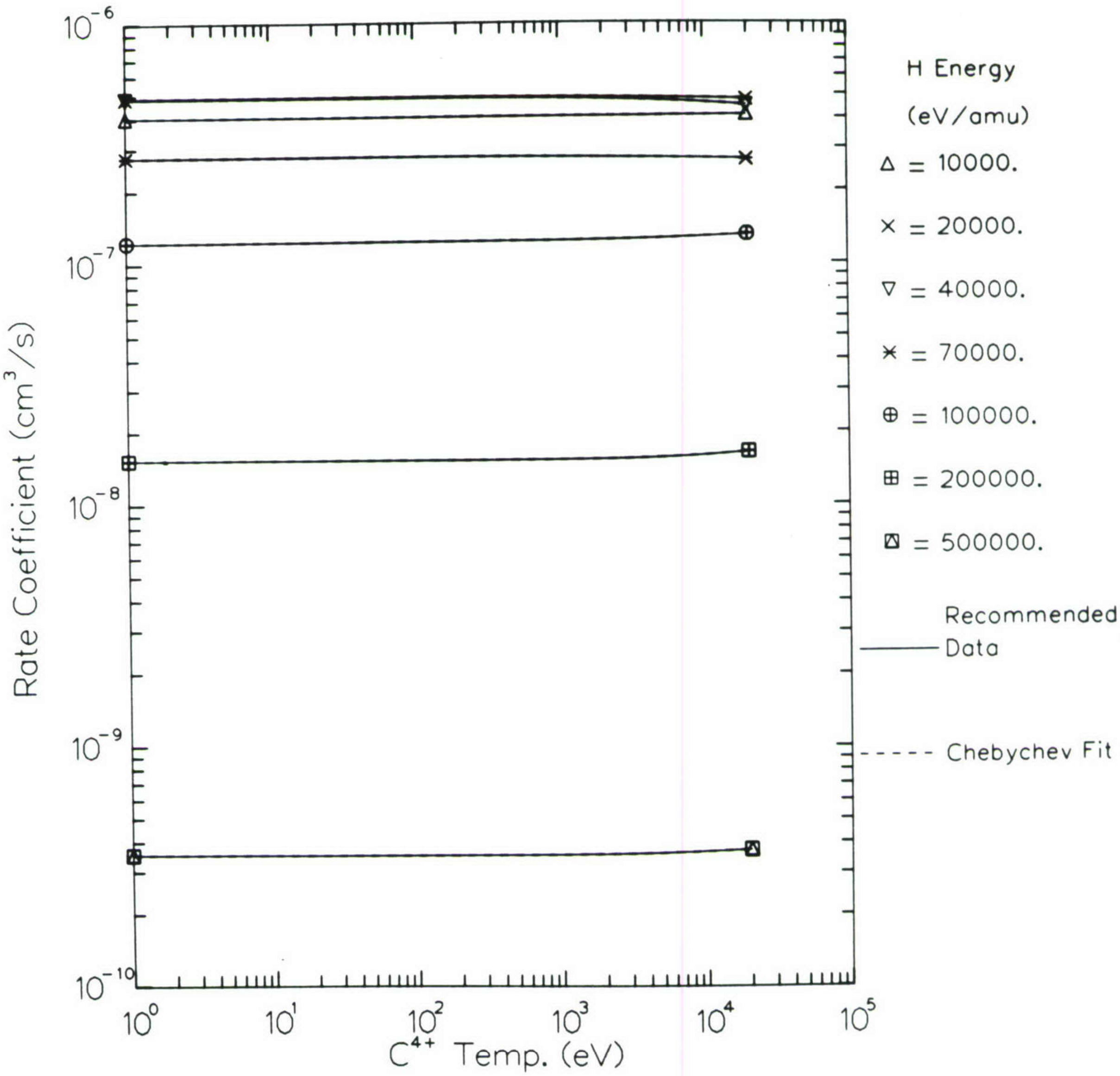
Chebychev Fitting Parameters for Rate Coefficients

H Energy (eV/amu)	C1	C2	C3	C4	C5	C6	C7
10000.	8.089E-07	2.709E-09	1.796E-09	1.051E-09	5.268E-10	2.007E-10	5.352E-11
20000.	9.673E-07	-5.645E-09	-3.150E-09	-1.395E-09	-5.632E-10	-2.436E-10	-1.284E-10
40000.	9.530E-07	-1.558E-08	-8.956E-09	-4.045E-09	-1.508E-09	-4.643E-10	-1.196E-10
70000.	5.465E-07	-3.744E-09	-2.015E-09	-8.449E-10	-3.057E-10	-1.027E-10	-3.778E-11
100000.	2.486E-07	2.918E-09	1.861E-09	9.496E-10	3.943E-10	1.282E-10	2.583E-11
200000.	3.097E-08	3.674E-10	2.699E-10	1.635E-10	8.345E-11	3.547E-11	1.347E-11
500000.	7.162E-10	5.802E-12	4.179E-12	2.506E-12	1.278E-12	5.557E-13	2.269E-13

See appendix for Chebychev fit details.

$H + C^{4+} \rightarrow C^{3+} + H^{+}$

Beam – Maxwellian



Total Electron Capture Cross Sections for
$C^{5+} + H \rightarrow C^{4+} + H^{+}$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
1.2E+00	1.55E+06	6.89E-15
2.0E+00	1.96E+06	5.95E-15
4.0E+00	2.78E+06	4.90E-15
7.0E+00	3.68E+06	4.27E-15
1.0E+01	4.39E+06	3.92E-15
2.0E+01	6.21E+06	3.32E-15
4.0E+01	8.79E+06	2.86E-15
7.0E+01	1.16E+07	2.52E-15
1.0E+02	1.39E+07	2.38E-15
2.0E+02	1.96E+07	2.07E-15
4.0E+02	2.78E+07	1.89E-15
7.0E+02	3.68E+07	1.89E-15
1.0E+03	4.39E+07	2.04E-15
1.7E+03	5.66E+07	2.20E-15
2.0E+03	6.21E+07	2.47E-15
4.0E+03	8.79E+07	3.05E-15
7.0E+03	1.16E+08	3.52E-15
1.0E+04	1.39E+08	3.70E-15
2.0E+04	1.96E+08	3.46E-15
4.0E+04	2.78E+08	2.32E-15
7.0E+04	3.68E+08	1.21E-15
1.0E+05	4.39E+08	5.69E-16
2.0E+05	6.21E+08	4.24E-17
4.0E+05	8.78E+08	2.24E-18

References: E.3, E.8, E.9, T.1, T.8, T.9, T.17, T.18

Accuracy: 30% for $1 \leq E(eV/amu) < 70$; 20% for $70 \leq E(eV/amu) \leq 2x10^5$; 30-50% for $E > 2x10^5$ eV/amu

Note: In the entire energy range $1 \leq E(eV/amu) \leq 1x10^5$, capture dominantly goes to the n=4 shell of the C^{4+} ion. The cross section minimum at E ~ 400 eV/amu results from the change of predominant role of states with different angular momentum [T.17].

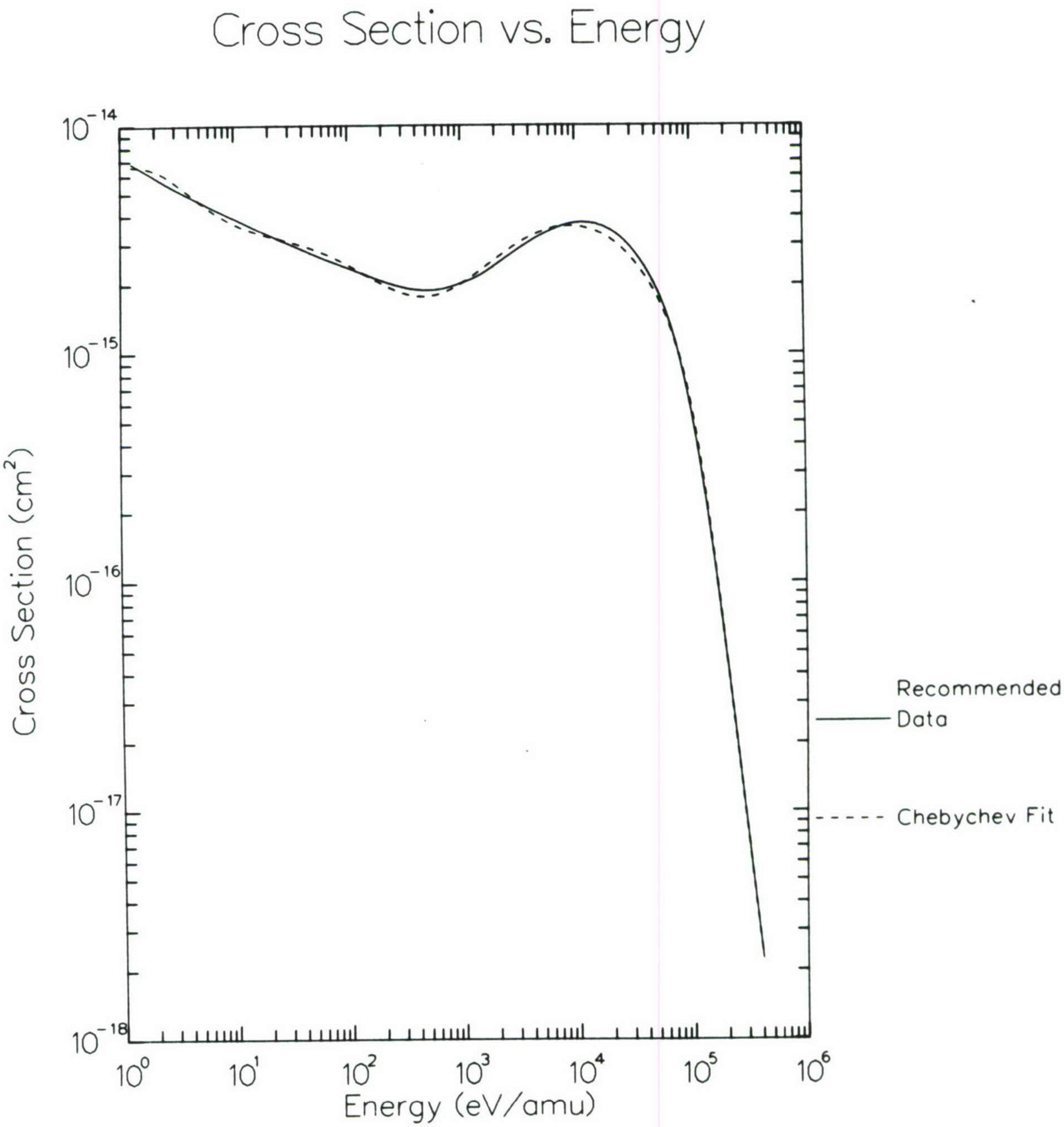
For Chebychev fits of the above cross sections it is necessary to use the following parameters.
E_{min} = 1.2E+00 eV/amu, E_{max} = 4.0E+05 eV/amu

Chebychev Fitting Parameters for Cross Sections

C1	C2	C3	C4	C5	C6	C7	C8	C9
5.782E-15	-2.671E-15	3.808E-16	-1.169E-15	-4.457E-17	4.381E-16	3.485E-16	1.186E-16	-2.898E-16

The fit represents the above cross sections with an rms deviation of 5.0%.
The maximum deviation is 8.7% at 1.7E+03 eV/amu.
See appendix for Chebychev fit details.

$C^{5+} + H \rightarrow C^{4+} + H^{+}$



Total Electron Capture Rate Coefficients for
$C^{5+} + H \rightarrow C^{4+} + H^{+}$

Maxwellian - Maxwellian Rate Coefficients (cm^3/s)

C^{5+} Temp. (eV)	Equal Temp.	H Temp. (eV) 1.	10.	100.	1000.	5000.	10000.	20000.
4.8E+00	1.51E-08	1.06E-08	1.82E-08	3.52E-08	1.20E-07	3.69E-07	4.98E-07	5.47E-07
8.4E+00	1.75E-08	1.12E-08	1.83E-08	3.52E-08	1.20E-07	3.69E-07	4.98E-07	5.47E-07
1.5E+01	2.04E-08	1.21E-08	1.85E-08	3.53E-08	1.20E-07	3.69E-07	4.98E-07	5.47E-07
2.4E+01	2.34E-08	1.31E-08	1.89E-08	3.54E-08	1.20E-07	3.69E-07	4.98E-07	5.47E-07
4.8E+01	2.86E-08	1.50E-08	1.97E-08	3.56E-08	1.20E-07	3.69E-07	4.98E-07	5.47E-07
8.4E+01	3.41E-08	1.69E-08	2.07E-08	3.59E-08	1.20E-07	3.69E-07	4.98E-07	5.47E-07
1.2E+02	3.85E-08	1.84E-08	2.17E-08	3.63E-08	1.21E-07	3.69E-07	4.98E-07	5.47E-07
2.4E+02	5.11E-08	2.20E-08	2.43E-08	3.74E-08	1.22E-07	3.70E-07	4.98E-07	5.47E-07
4.8E+02	7.54E-08	2.67E-08	2.83E-08	3.95E-08	1.23E-07	3.70E-07	4.98E-07	5.47E-07
8.4E+02	1.12E-07	3.15E-08	3.27E-08	4.25E-08	1.26E-07	3.72E-07	4.99E-07	5.47E-07
1.2E+03	1.46E-07	3.53E-08	3.63E-08	4.54E-08	1.29E-07	3.73E-07	4.99E-07	5.47E-07
2.4E+03	2.43E-07	4.55E-08	4.64E-08	5.49E-08	1.37E-07	3.77E-07	5.01E-07	5.47E-07
4.8E+03	3.77E-07	6.42E-08	6.51E-08	7.35E-08	1.54E-07	3.85E-07	5.03E-07	5.47E-07
8.4E+03	4.83E-07	9.23E-08	9.32E-08	1.02E-07	1.79E-07	3.96E-07	5.07E-07	5.46E-07
1.2E+04	5.30E-07	1.20E-07	1.21E-07	1.29E-07	2.02E-07	4.06E-07	5.11E-07	5.46E-07
2.0E+04	5.45E-07	1.76E-07	1.76E-07	1.83E-07	2.47E-07	4.27E-07	5.18E-07	5.45E-07

Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 4.8E+00 eV, E_{max} = 2.0E+04 eV

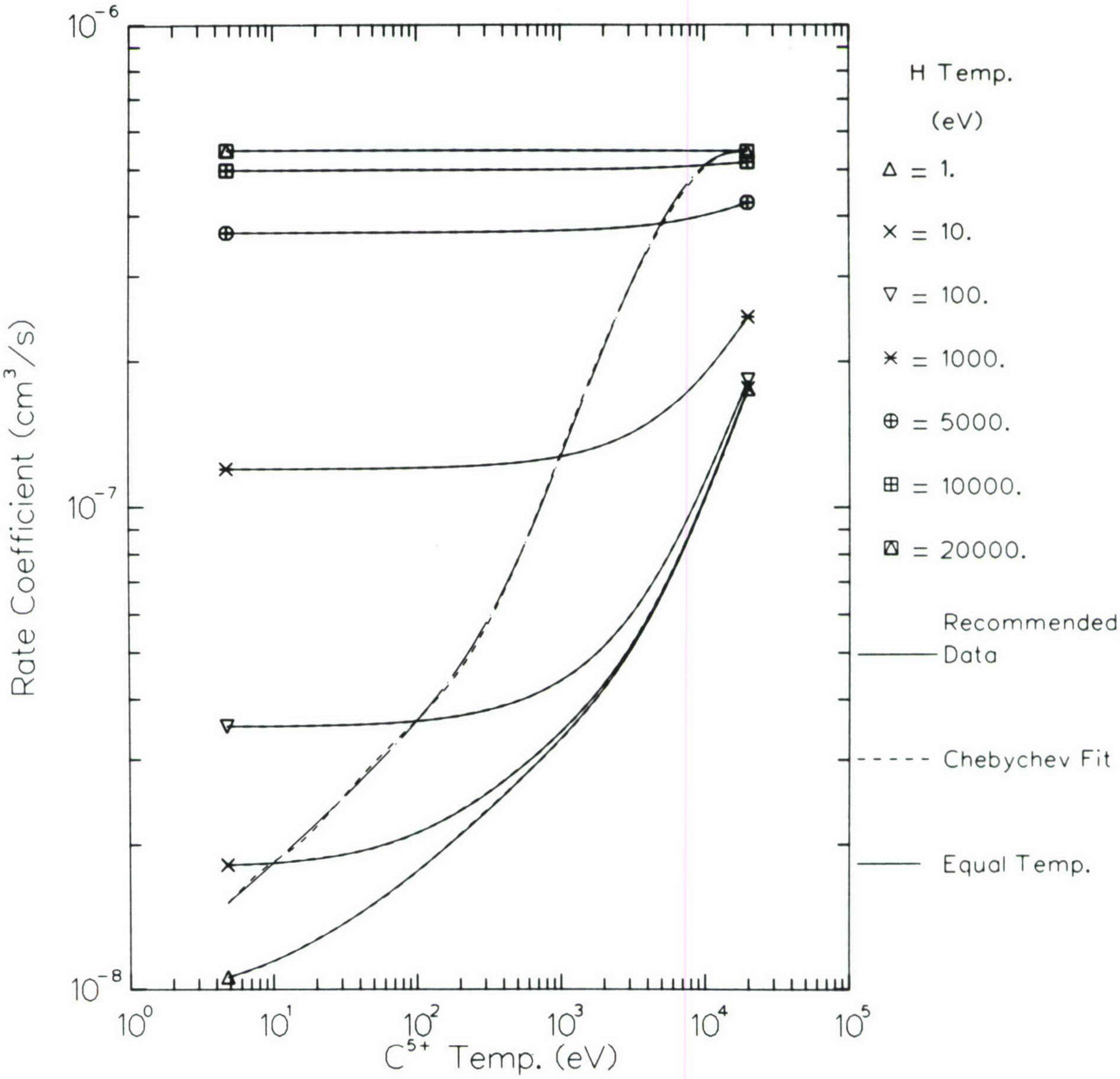
Chebychev Fitting Parameters for Rate Coefficients

H Temp. (eV)	C1	C2	C3	C4	C5	C6	C7
1.	1.011E-07	6.278E-08	3.410E-08	1.691E-08	7.900E-09	2.967E-09	6.905E-10
10.	1.078E-07	5.915E-08	3.515E-08	1.718E-08	7.681E-09	2.957E-09	7.290E-10
100.	1.325E-07	5.366E-08	3.511E-08	1.808E-08	7.493E-09	2.458E-09	5.455E-10
1000.	2.937E-07	4.676E-08	3.043E-08	1.530E-08	5.976E-09	1.756E-09	3.273E-10
5000.	7.622E-07	2.115E-08	1.375E-08	6.906E-09	2.694E-09	7.897E-10	1.442E-10
10000.	1.004E-06	7.611E-09	4.934E-09	2.458E-09	9.445E-10	2.666E-10	4.098E-11
20000.	1.093E-06	-7.966E-10	-5.679E-10	-3.431E-10	-1.774E-10	-8.176E-11	-3.602E-11
Equal Temp.	3.856E-07	2.718E-07	1.189E-07	1.480E-08	-2.289E-08	-1.893E-08	-5.971E-09

See appendix for Chebychev fit details.

$C^{5+} + H \rightarrow C^{4+} + H^{+}$

Maxwellian — Maxwellian



Total Electron Capture Rate Coefficients for
$H + C^{5+} \rightarrow C^{4+} + H^+$

Beam - Maxwellian Rate Coefficients (cm^3/s)

C^{5+} Temp. (eV)	H Energy (eV/amu) 10000.	20000.	40000.	70000.	100000.	200000.	500000.
4.8E+00	5.14E-07	6.80E-07	6.44E-07	4.45E-07	2.51E-07	2.61E-08	7.95E-10
8.4E+00	5.14E-07	6.80E-07	6.44E-07	4.44E-07	2.50E-07	2.64E-08	7.97E-10
1.5E+01	5.14E-07	6.79E-07	6.44E-07	4.44E-07	2.50E-07	2.64E-08	7.97E-10
2.4E+01	5.14E-07	6.79E-07	6.44E-07	4.44E-07	2.50E-07	2.64E-08	7.97E-10
4.8E+01	5.14E-07	6.79E-07	6.44E-07	4.44E-07	2.50E-07	2.64E-08	7.97E-10
8.4E+01	5.14E-07	6.79E-07	6.44E-07	4.44E-07	2.50E-07	2.64E-08	7.97E-10
1.2E+02	5.14E-07	6.79E-07	6.44E-07	4.44E-07	2.50E-07	2.64E-08	7.97E-10
2.4E+02	5.13E-07	6.78E-07	6.44E-07	4.43E-07	2.50E-07	2.65E-08	7.98E-10
4.8E+02	5.14E-07	6.77E-07	6.43E-07	4.43E-07	2.49E-07	2.66E-08	7.98E-10
8.4E+02	5.14E-07	6.77E-07	6.42E-07	4.42E-07	2.49E-07	2.67E-08	7.99E-10
1.2E+03	5.13E-07	6.76E-07	6.42E-07	4.41E-07	2.49E-07	2.68E-08	7.99E-10
2.4E+03	5.15E-07	6.72E-07	6.40E-07	4.39E-07	2.49E-07	2.70E-08	8.02E-10
4.8E+03	5.16E-07	6.69E-07	6.35E-07	4.37E-07	2.49E-07	2.75E-08	8.06E-10
8.4E+03	5.19E-07	6.64E-07	6.31E-07	4.33E-07	2.49E-07	2.82E-08	8.13E-10
1.2E+04	5.23E-07	6.58E-07	6.25E-07	4.31E-07	2.49E-07	2.88E-08	8.20E-10
2.0E+04	5.29E-07	6.48E-07	6.16E-07	4.25E-07	2.49E-07	3.01E-08	8.36E-10

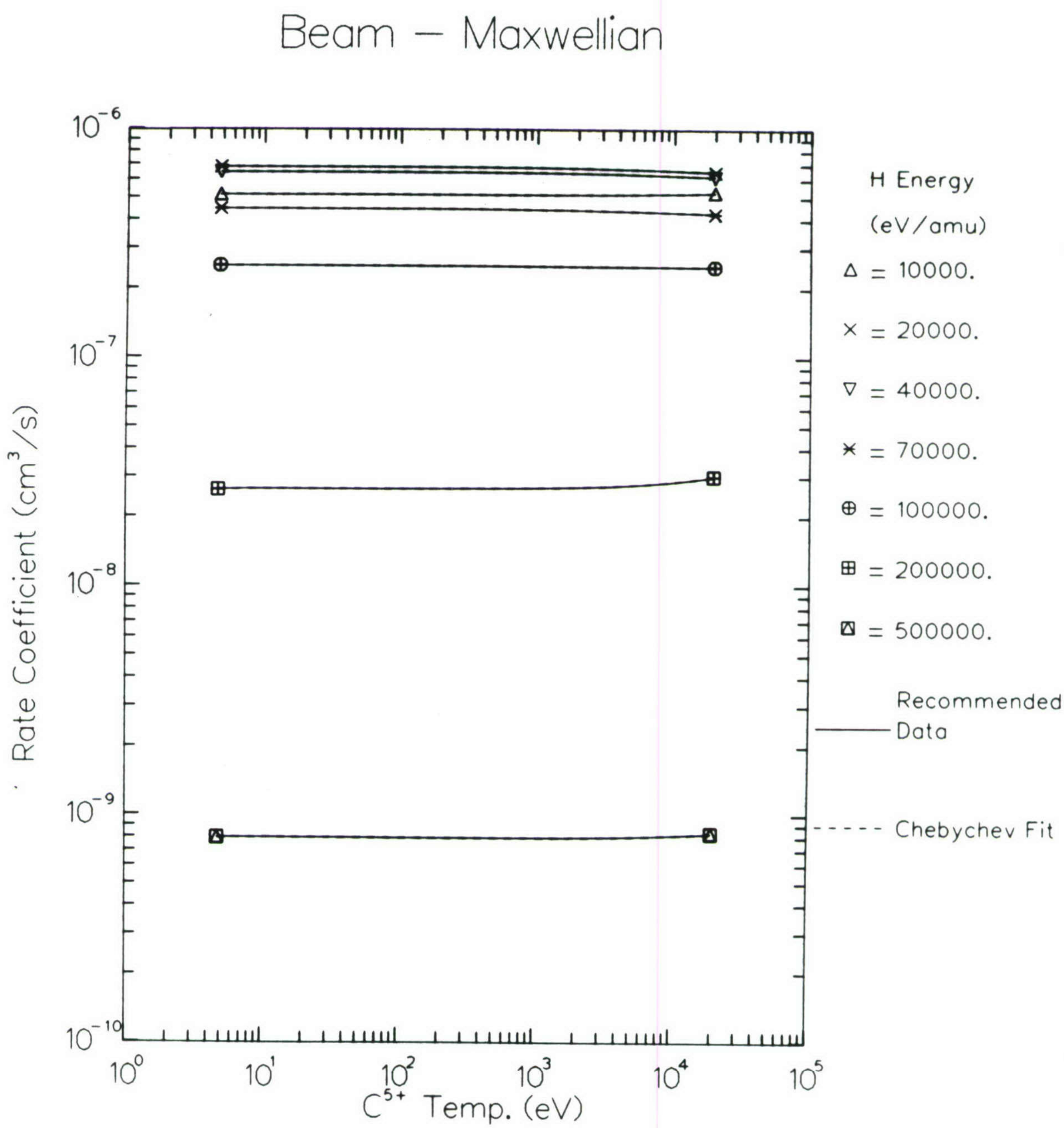
Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 4.8E+00 eV, E_{max} = 2.0E+04 eV

Chebychev Fitting Parameters for Rate Coefficients

H Energy (eV/amu)	C1	C2	C3	C4	C5	C6	C7
10000.	1.033E-06	4.924E-09	3.826E-09	2.214E-09	9.006E-10	2.239E-10	7.497E-12
20000.	1.344E-06	-1.224E-08	-7.057E-09	-3.188E-09	-1.205E-09	-4.075E-10	-1.050E-10
40000.	1.276E-06	-1.075E-08	-6.541E-09	-3.077E-09	-1.218E-09	-3.528E-10	-1.195E-10
70000.	8.788E-07	-8.080E-09	-4.144E-09	-1.729E-09	-5.362E-10	-2.019E-10	-1.026E-11
100000.	4.991E-07	-6.386E-10	8.629E-11	-3.569E-11	1.552E-10	-8.245E-11	5.639E-11
200000.	5.438E-08	1.433E-09	8.050E-10	4.417E-10	1.336E-10	9.129E-11	-1.294E-11
500000.	1.609E-09	1.407E-11	8.809E-12	5.359E-12	1.975E-12	1.088E-12	1.583E-13

See appendix for Chebychev fit details.

$H + C^{5+} \rightarrow C^{4+} + H^{+}$



Total Electron Capture Cross Sections for
$C^{6+} + H \rightarrow C^{5+} + H^+$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
1.0E+00	1.39E+06	2.85E-18
2.0E+00	1.96E+06	2.39E-18
4.0E+00	2.78E+06	3.04E-18
7.0E+00	3.68E+06	8.96E-18
1.0E+01	4.39E+06	1.78E-17
2.0E+01	6.21E+06	5.98E-17
4.0E+01	8.79E+06	1.92E-16
7.0E+01	1.16E+07	4.20E-16
1.0E+02	1.39E+07	6.53E-16
2.0E+02	1.96E+07	1.36E-15
4.0E+02	2.78E+07	2.27E-15
7.0E+02	3.68E+07	3.11E-15
1.0E+03	4.39E+07	3.53E-15
1.6E+03	5.56E+07	4.00E-15
2.0E+03	6.21E+07	4.07E-15
4.0E+03	8.79E+07	4.39E-15
7.0E+03	1.16E+08	4.35E-15
1.0E+04	1.39E+08	4.15E-15
2.0E+04	1.96E+08	3.46E-15
4.0E+04	2.78E+08	2.50E-15
7.0E+04	3.68E+08	1.29E-15
1.0E+05	4.39E+08	7.23E-16
2.0E+05	6.21E+08	7.97E-17
4.0E+05	8.78E+08	1.78E-18
7.0E+05	1.16E+09	7.57E-20

References: E.3, E.8, E.9, E.11, T.8, T.9, T.19, T.20, T.21, T.22, T.23, T.24, T.25, T.26, T.27, T.28

Accuracy: 25-30% for $1 \leq E(eV/amu) < 10^2$; 20% for $100 \leq E(eV/amu) < 10^3$; 15% for $10^3 \leq E(eV/amu) \leq 2x10^5$; 20-25% for $E > 2x10^5$ eV/amu

Notes: (1) In the region below 1 eV/amu, the cross section continues to increase with decreasing energy, reaching a value of $\sigma = 1.4x10^{-17}$ cm^2 at $E = 5.6x10^{-2}$ eV/amu [T.21].
(2) For E < 3.26 eV/amu the n=5 shell of C^{5+} is dominantly populated, while above this energy (up to ~ $1x10^6$ eV/amu) capture goes dominantly to the n = 4 shell of C^{5+} [T.21], [T.22], [T.23].
(3) In the energy region $10 \leq E(eV/amu) \leq 10^5$, the 4f final state of C^{5+} is the most populated except for energies between $5x10^2$-$5x10^3$ eV/amu where 4d dominates slightly over 4f [T.19], [T.22].

For Chebychev fits of the above cross sections it is necessary to use the following parameters.
E_{min} = 1.0E+00 eV/amu, E_{max} = 7.0E+05 eV/amu

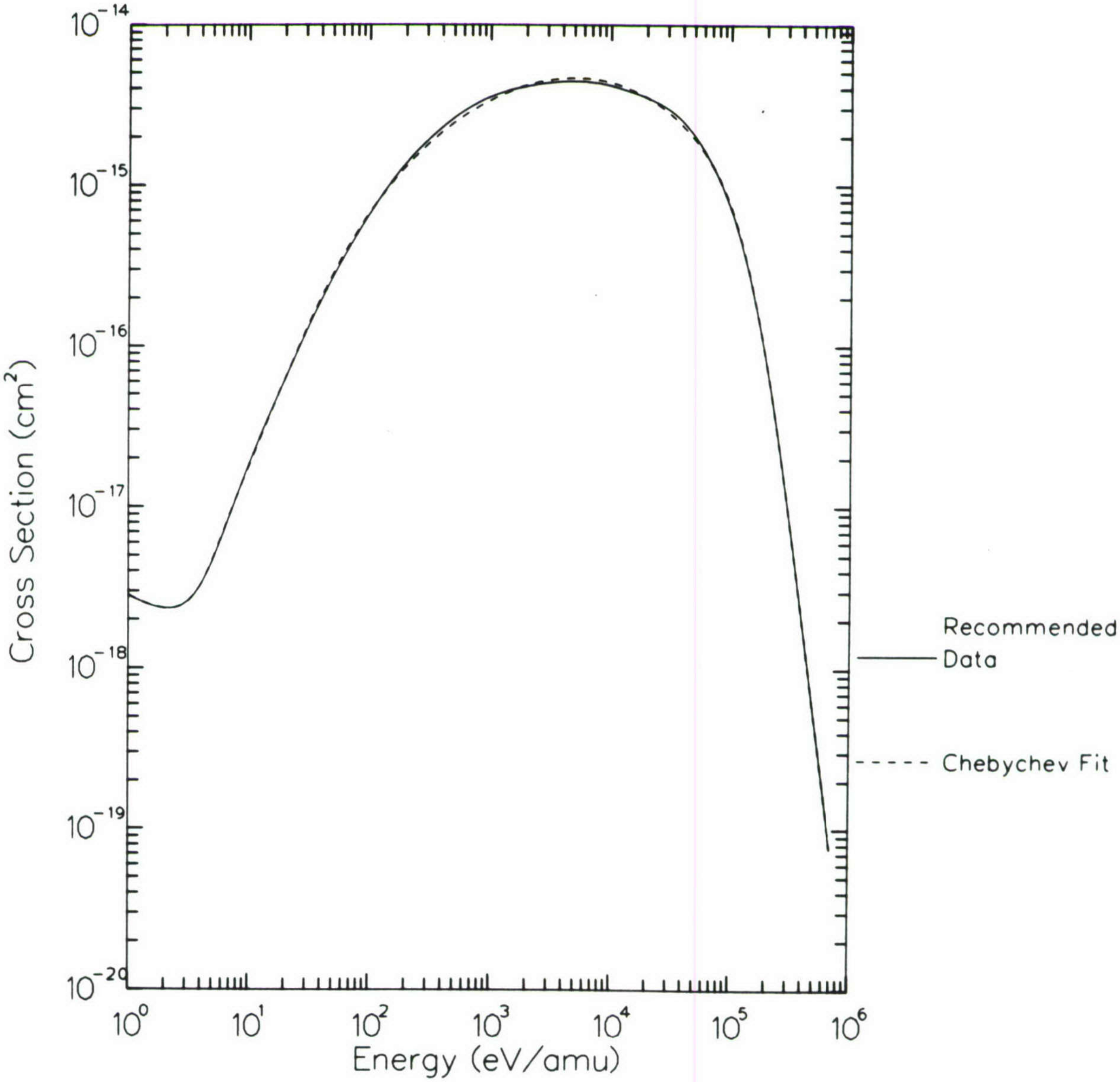
Chebychev Fitting Parameters for Cross Sections

C1	C2	C3	C4	C5	C6	C7	C8	C9
2.144E-15	5.072E-16	-1.599E-15	-1.028E-15	5.844E-16	7.532E-16	3.431E-17	-2.336E-16	-8.989E-17

The fit represents the above cross sections with an rms deviation of 3.8%.
The maximum deviation is 4.5% at 7.0E+03 eV/amu.
See appendix for Chebychev fit details.

$C^{6+} + H \rightarrow C^{5+} + H^{+}$

Cross Section vs. Energy



Total Electron Capture Rate Coefficients for
$C^{6+} + H \rightarrow C^{5+} + H^{+}$

Maxwellian - Maxwellian Rate Coefficients (cm^3/s)

C^{6+} Temp. (eV)	Equal Temp.	H Temp. (eV) 1.	10.	100.	1000.	5000.	10000.	20000.
1.0E+00	5.27E-12	5.27E-12	3.72E-10	1.91E-08	1.84E-07	4.45E-07	5.51E-07	5.88E-07
1.2E+00	6.21E-12	5.33E-12	3.73E-10	1.91E-08	1.84E-07	4.45E-07	5.51E-07	5.88E-07
2.4E+00	1.95E-11	5.74E-12	3.81E-10	1.92E-08	1.84E-07	4.45E-07	5.51E-07	5.88E-07
4.8E+00	8.90E-11	6.76E-12	3.97E-10	1.92E-08	1.85E-07	4.45E-07	5.51E-07	5.88E-07
8.4E+00	3.00E-10	8.86E-12	4.21E-10	1.93E-08	1.85E-07	4.45E-07	5.51E-07	5.88E-07
1.2E+01	6.27E-10	1.17E-11	4.46E-10	1.94E-08	1.85E-07	4.45E-07	5.51E-07	5.88E-07
2.4E+01	2.34E-09	2.65E-11	5.33E-10	1.96E-08	1.85E-07	4.45E-07	5.51E-07	5.88E-07
4.8E+01	7.45E-09	8.16E-11	7.27E-10	2.01E-08	1.85E-07	4.45E-07	5.51E-07	5.88E-07
8.4E+01	1.68E-08	2.28E-10	1.06E-09	2.09E-08	1.85E-07	4.46E-07	5.51E-07	5.88E-07
1.2E+02	2.68E-08	4.46E-10	1.45E-09	2.17E-08	1.86E-07	4.46E-07	5.51E-07	5.88E-07
2.4E+02	5.88E-08	1.59E-09	3.01E-09	2.42E-08	1.87E-07	4.46E-07	5.51E-07	5.88E-07
4.8E+02	1.12E-07	5.10E-09	7.01E-09	2.93E-08	1.90E-07	4.47E-07	5.52E-07	5.88E-07
8.4E+02	1.73E-07	1.19E-08	1.41E-08	3.70E-08	1.93E-07	4.48E-07	5.52E-07	5.88E-07
1.2E+03	2.20E-07	1.94E-08	2.17E-08	4.44E-08	1.97E-07	4.49E-07	5.52E-07	5.88E-07
2.4E+03	3.30E-07	4.47E-08	4.69E-08	6.80E-08	2.09E-07	4.52E-07	5.53E-07	5.88E-07
4.8E+03	4.52E-07	8.94E-08	9.12E-08	1.08E-07	2.31E-07	4.59E-07	5.56E-07	5.88E-07
8.4E+03	5.39E-07	1.42E-07	1.44E-07	1.57E-07	2.60E-07	4.68E-07	5.59E-07	5.87E-07
1.2E+04	5.77E-07	1.85E-07	1.86E-07	1.97E-07	2.86E-07	4.76E-07	5.62E-07	5.87E-07
1.9E+04	5.87E-07	2.51E-07	2.52E-07	2.60E-07	3.30E-07	4.92E-07	5.67E-07	5.85E-07

Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.0E+00 eV, E_{max} = 1.9E+04 eV

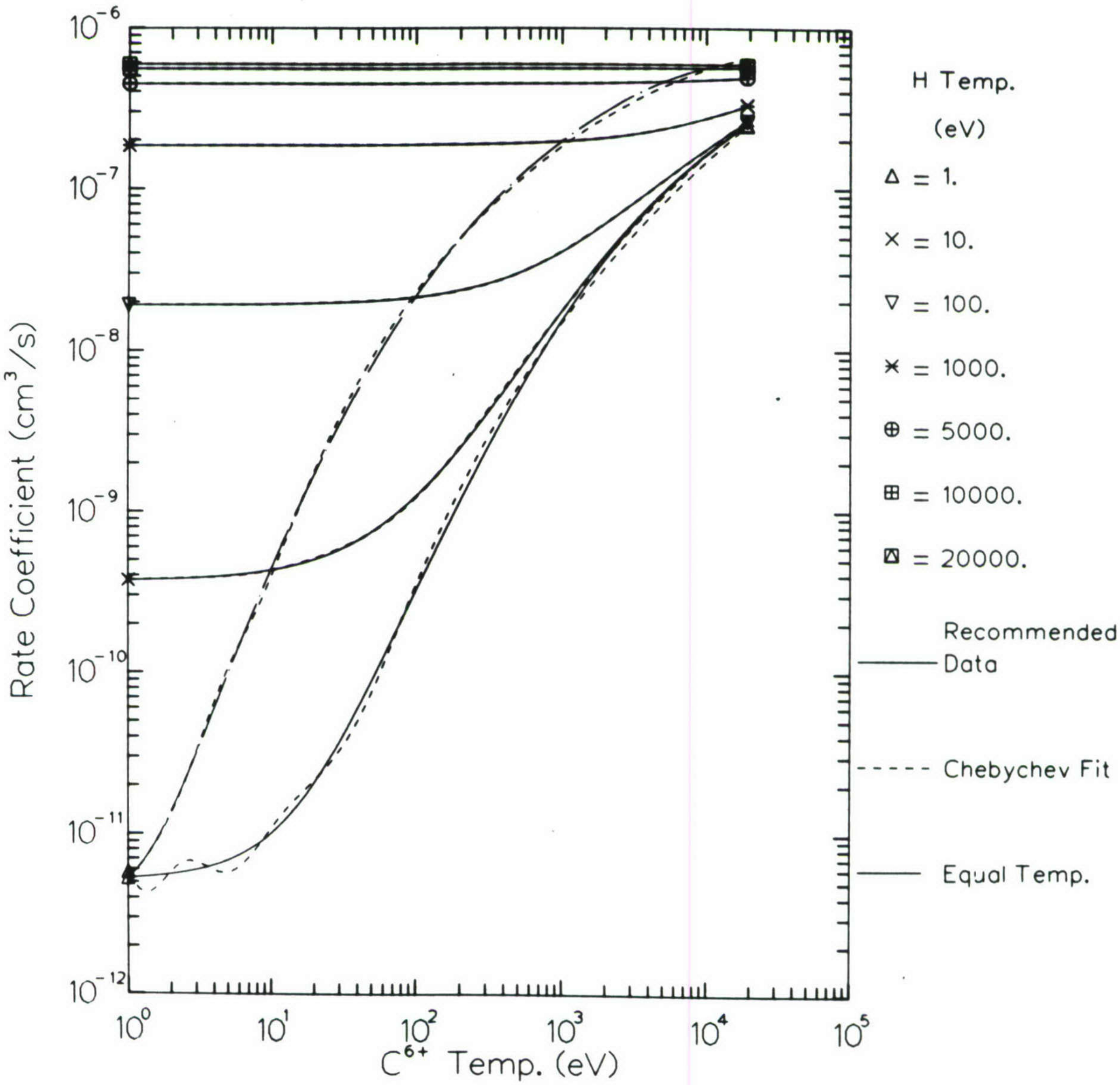
Chebychev Fitting Parameters for Rate Coefficients

H Temp. (eV)	C1	C2	C3	C4	C5	C6	C7
1.	9.851E-08	8.743E-08	6.074E-08	3.233E-08	1.258E-08	3.236E-09	4.207E-10
10.	1.095E-07	9.624E-08	6.645E-08	3.528E-08	1.383E-08	3.633E-09	4.851E-10
100.	1.429E-07	9.090E-08	5.969E-08	2.927E-08	1.013E-08	1.993E-09	-5.878E-11
1000.	4.283E-07	5.211E-08	3.547E-08	1.876E-08	7.582E-09	2.168E-09	2.754E-10
5000.	9.089E-07	1.610E-08	1.123E-08	6.254E-09	2.792E-09	9.745E-10	2.445E-10
10000.	1.108E-06	5.538E-09	3.860E-09	2.148E-09	9.559E-10	3.312E-10	8.022E-11
20000.	1.175E-06	-8.462E-10	-6.268E-10	-3.973E-10	-2.195E-10	-1.050E-10	-4.853E-11
Equal Temp.	3.837E-07	3.070E-07	1.474E-07	2.644E-08	-1.331E-08	-9.416E-09	-1.868E-09

See appendix for Chebychev fit details.

$C^{6+} + H \rightarrow C^{5+} + H^{+}$

Maxwellian — Maxwellian



Total Electron Capture Rate Coefficients for
$H + C^{6+} \rightarrow C^{5+} + H^{+}$

Beam - Maxwellian Rate Coefficients (cm^3/s)

C^{6+} Temp. (eV)	H Energy (eV/amu) 10000.	20000.	40000.	70000.	100000.	200000.	500000.
1.0E+00	5.76E-07	6.80E-07	6.94E-07	4.74E-07	3.18E-07	4.95E-08	5.01E-10
1.2E+00	5.76E-07	6.80E-07	6.94E-07	4.74E-07	3.18E-07	4.95E-08	5.01E-10
2.4E+00	5.76E-07	6.80E-07	6.94E-07	4.74E-07	3.17E-07	4.95E-08	5.01E-10
4.8E+00	5.76E-07	6.80E-07	6.94E-07	4.74E-07	3.17E-07	4.95E-08	5.01E-10
8.4E+00	5.76E-07	6.80E-07	6.94E-07	4.74E-07	3.17E-07	4.95E-08	5.01E-10
1.2E+01	5.76E-07	6.80E-07	6.94E-07	4.74E-07	3.17E-07	4.95E-08	5.01E-10
2.4E+01	5.76E-07	6.80E-07	6.94E-07	4.74E-07	3.17E-07	4.95E-08	5.01E-10
4.8E+01	5.76E-07	6.80E-07	6.93E-07	4.74E-07	3.17E-07	4.95E-08	5.01E-10
8.4E+01	5.76E-07	6.80E-07	6.93E-07	4.74E-07	3.17E-07	4.95E-08	5.01E-10
1.2E+02	5.76E-07	6.80E-07	6.93E-07	4.74E-07	3.17E-07	4.95E-08	5.01E-10
2.4E+02	5.76E-07	6.79E-07	6.92E-07	4.74E-07	3.17E-07	4.95E-08	5.01E-10
4.8E+02	5.77E-07	6.79E-07	6.90E-07	4.74E-07	3.16E-07	4.95E-08	5.02E-10
8.4E+02	5.76E-07	6.79E-07	6.89E-07	4.74E-07	3.16E-07	4.96E-08	5.03E-10
1.2E+03	5.75E-07	6.79E-07	6.88E-07	4.74E-07	3.15E-07	4.97E-08	5.03E-10
2.4E+03	5.76E-07	6.77E-07	6.84E-07	4.74E-07	3.14E-07	4.99E-08	5.06E-10
4.8E+03	5.76E-07	6.76E-07	6.77E-07	4.73E-07	3.13E-07	5.02E-08	5.10E-10
8.4E+03	5.77E-07	6.74E-07	6.71E-07	4.72E-07	3.12E-07	5.09E-08	5.18E-10
1.2E+04	5.78E-07	6.71E-07	6.64E-07	4.71E-07	3.10E-07	5.15E-08	5.25E-10
1.9E+04	5.80E-07	6.67E-07	6.53E-07	4.68E-07	3.08E-07	5.28E-08	5.41E-10

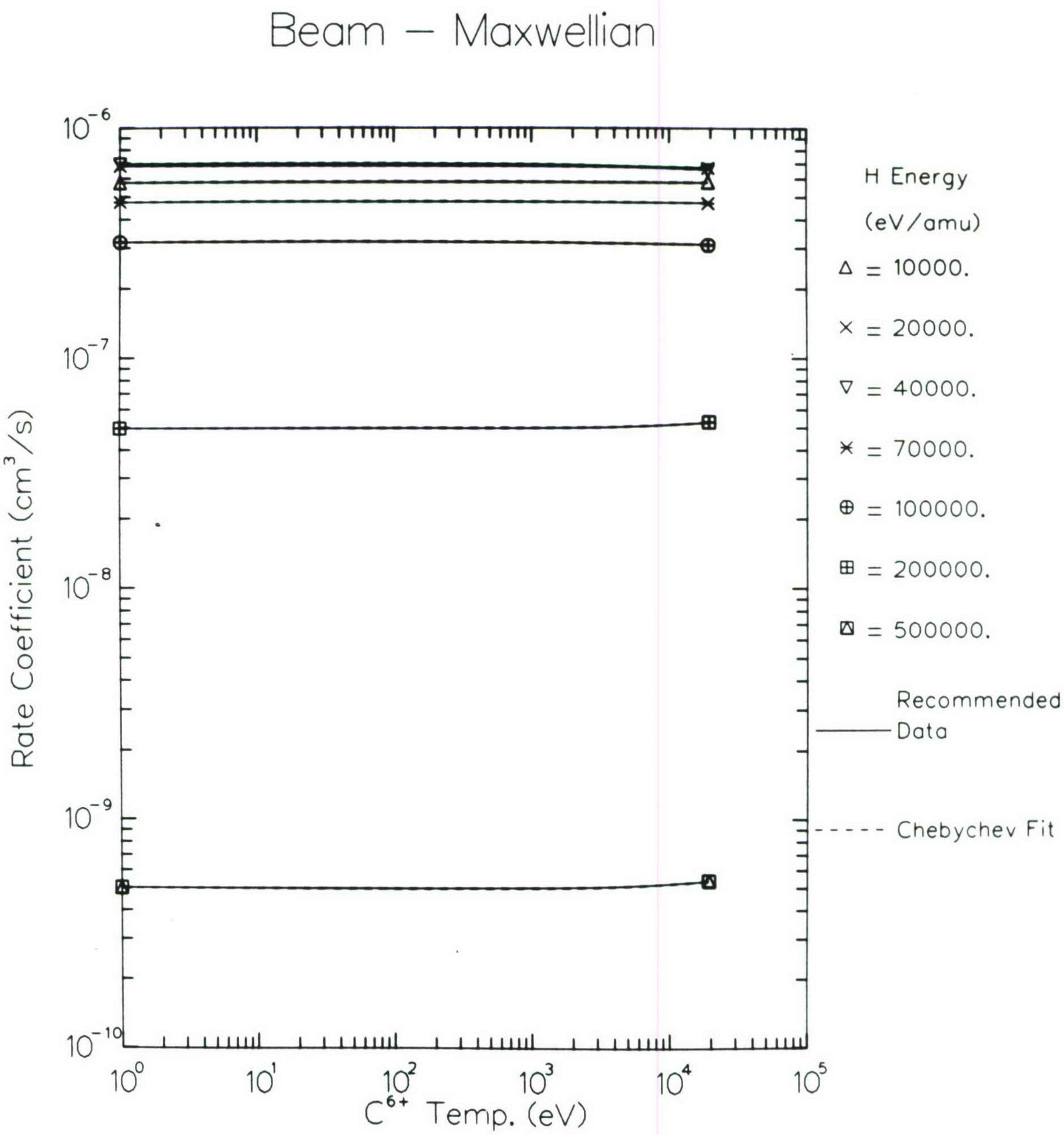
Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.0E+00 eV, E_{max} = 1.9E+04 eV

Chebychev Fitting Parameters for Rate Coefficients

H Energy (eV/amu)	C1	C2	C3	C4	C5	C6	C7
10000.	1.154E-06	7.691E-10	8.184E-10	7.084E-10	4.355E-10	1.752E-10	5.918E-11
20000.	1.354E-06	-4.496E-09	-2.925E-09	-1.539E-09	-7.068E-10	-3.138E-10	-1.479E-10
40000.	1.369E-06	-1.592E-08	-9.236E-09	-4.216E-09	-1.576E-09	-4.735E-10	-1.041E-10
70000.	9.465E-07	-1.681E-09	-1.414E-09	-9.656E-10	-5.375E-10	-2.450E-10	-1.023E-10
100000.	6.302E-07	-3.811E-09	-1.967E-09	-7.347E-10	-1.975E-10	-3.126E-11	2.348E-12
200000.	1.002E-07	1.064E-09	7.877E-10	4.760E-10	2.392E-10	9.871E-11	3.545E-11
500000.	1.016E-09	1.301E-11	9.371E-12	5.623E-12	2.868E-12	1.247E-12	5.081E-13

See appendix for Chebychev fit details.

$H + C^{6+} \rightarrow C^{5+} + H^+$



Total Electron Capture Cross Sections for
$O^+ + H \rightarrow O + H^+$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
1.0E+00	1.39E+06	1.61E-15
2.0E+00	1.96E+06	1.50E-15
4.0E+00	2.78E+06	1.41E-15
7.0E+00	3.68E+06	1.31E-15
1.0E+01	4.39E+06	1.25E-15
2.0E+01	6.21E+06	1.17E-15
4.0E+01	8.79E+06	1.08E-15
7.0E+01	1.16E+07	1.01E-15
1.0E+02	1.39E+07	9.77E-16
2.0E+02	1.96E+07	9.05E-16
4.0E+02	2.78E+07	8.22E-16
7.0E+02	3.68E+07	7.27E-16
1.0E+03	4.39E+07	6.81E-16
1.3E+03	4.91E+07	6.50E-16
2.0E+03	6.21E+07	5.65E-16
4.0E+03	8.79E+07	4.27E-16
7.0E+03	1.16E+08	3.21E-16
1.0E+04	1.39E+08	2.56E-16
2.0E+04	1.96E+08	1.52E-16
4.0E+04	2.78E+08	7.56E-17
7.0E+04	3.68E+08	3.42E-17
1.0E+05	4.39E+08	1.91E-17
2.0E+05	6.21E+08	3.62E-18
3.7E+05	8.46E+08	4.28E-19

References: E.1, E.12, E.13, E.14, E.15, T.1, T.9, T.29

Accuracy: 20% for $1 \leq E(\mathrm{eV/amu}) \leq 5\times10^4$; 30-40% for $E > 5\times10^4$ eV/amu

Note: The reaction $O^+(^4S) + H \rightarrow O(^3P_J) + H^+$ (J = 0,1,2) is quasi-resonant with an accidental resonance for the J=1 sub-level. The cross section continues to increase logarithmically with decreasing energy below 1 eV/amu. The contributions to the total cross section from capture to the J=2 and J=0 states become negligible below $E = 6\times10^{-3}$ eV/amu and $E = 5\times10^{-4}$ eV/amu, respectively [T.29]. At $E = 10^{-2}$ eV/amu the cross section has a value of $\sigma = 2.5\times10^{-15}$ cm^2 (within 30% accuracy).

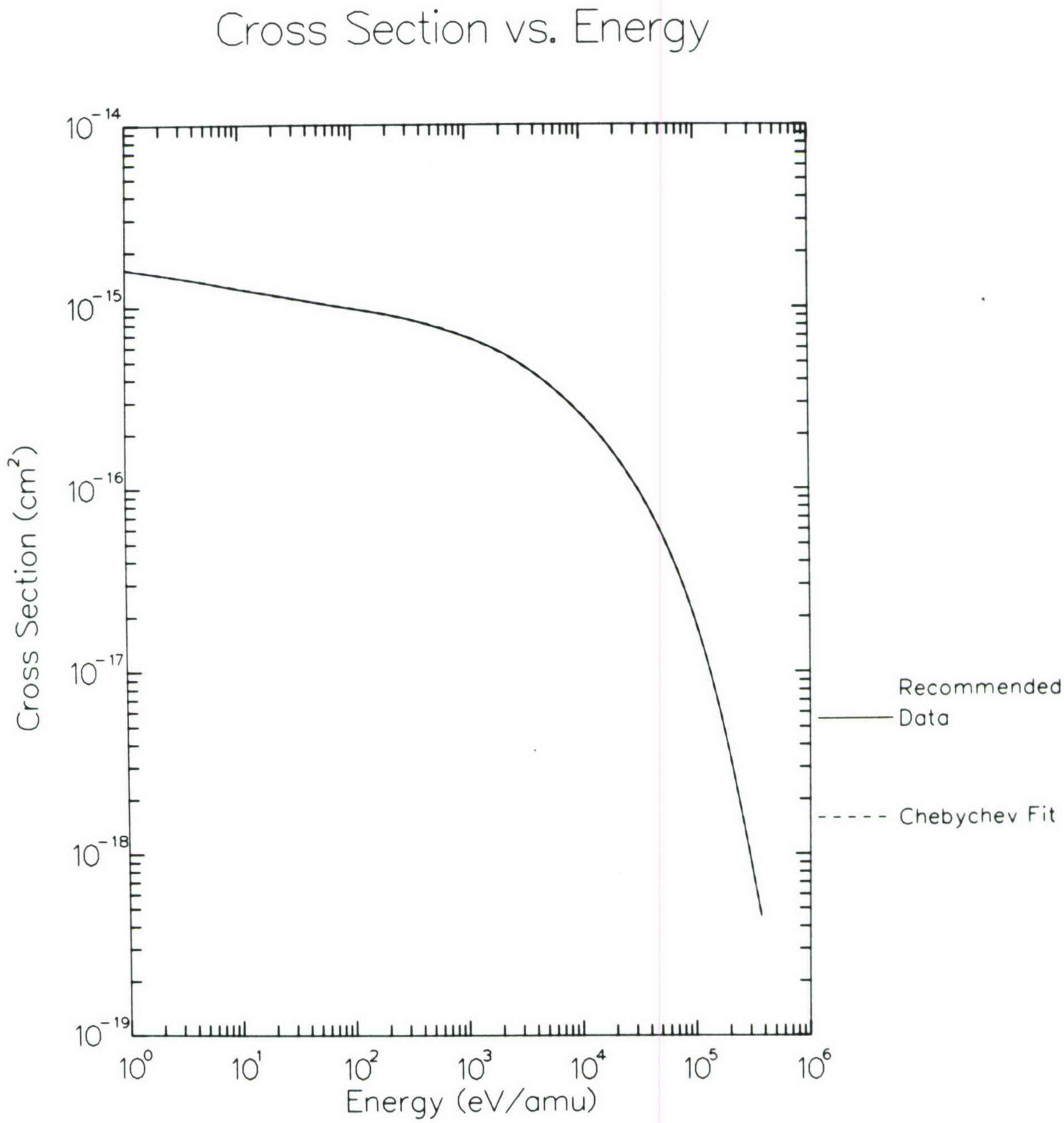
For Chebychev fits of the above cross sections it is necessary to use the following parameters.
E_{min} = 1.0E+00 eV/amu, E_{max} = 3.7E+05 eV/amu

Chebychev Fitting Parameters for Cross Sections

C1	C2	C3	C4	C5	C6	C7	C8	C9
1.460E-15	-8.501E-16	4.143E-17	4.592E-17	4.831E-17	3.233E-18	-1.884E-17	-3.710E-18	4.433E-18

The fit represents the above cross sections with an rms deviation of 0.7%.
The maximum deviation is 1.7% at 7.0E+04 eV/amu.
See appendix for Chebychev fit details.

$O^+ + H \rightarrow O + H^+$



Total Electron Capture Rate Coefficients for
$O^{+} + H \rightarrow O + H^{+}$

Maxwellian - Maxwellian Rate Coefficients (cm^3/s)

O^+ Temp. (eV)	Equal Temp.	H Temp. (eV) 1.	10.	100.	1000.	5000.	10000.	20000.
1.0E+00	2.49E-09	2.49E-09	5.99E-09	1.46E-08	2.98E-08	3.46E-08	3.21E-08	2.65E-08
1.1E+00	2.60E-09	2.50E-09	5.99E-09	1.46E-08	2.98E-08	3.46E-08	3.21E-08	2.65E-08
1.6E+00	3.00E-09	2.52E-09	6.00E-09	1.46E-08	2.98E-08	3.46E-08	3.21E-08	2.65E-08
3.2E+00	3.93E-09	2.61E-09	6.02E-09	1.46E-08	2.98E-08	3.46E-08	3.21E-08	2.65E-08
6.4E+00	5.14E-09	2.78E-09	6.07E-09	1.46E-08	2.98E-08	3.46E-08	3.21E-08	2.65E-08
1.1E+01	6.39E-09	3.00E-09	6.14E-09	1.46E-08	2.98E-08	3.46E-08	3.21E-08	2.65E-08
1.6E+01	7.35E-09	3.20E-09	6.20E-09	1.46E-08	2.98E-08	3.46E-08	3.21E-08	2.65E-08
3.2E+01	9.62E-09	3.74E-09	6.42E-09	1.47E-08	2.98E-08	3.46E-08	3.21E-08	2.65E-08
6.4E+01	1.26E-08	4.56E-09	6.81E-09	1.48E-08	2.99E-08	3.46E-08	3.21E-08	2.65E-08
1.1E+02	1.56E-08	5.48E-09	7.35E-09	1.50E-08	2.99E-08	3.46E-08	3.21E-08	2.65E-08
1.6E+02	1.77E-08	6.20E-09	7.83E-09	1.51E-08	2.99E-08	3.46E-08	3.21E-08	2.65E-08
3.2E+02	2.23E-08	7.98E-09	9.16E-09	1.56E-08	3.00E-08	3.46E-08	3.21E-08	2.65E-08
6.4E+02	2.72E-08	1.04E-08	1.12E-08	1.65E-08	3.01E-08	3.46E-08	3.20E-08	2.65E-08
1.1E+03	3.09E-08	1.28E-08	1.34E-08	1.77E-08	3.02E-08	3.46E-08	3.20E-08	2.65E-08
1.6E+03	3.27E-08	1.46E-08	1.51E-08	1.87E-08	3.04E-08	3.46E-08	3.20E-08	2.65E-08
3.2E+03	3.47E-08	1.88E-08	1.90E-08	2.14E-08	3.09E-08	3.46E-08	3.20E-08	2.64E-08
6.4E+03	3.39E-08	2.35E-08	2.36E-08	2.51E-08	3.18E-08	3.45E-08	3.18E-08	2.63E-08
1.1E+04	3.09E-08	2.75E-08	2.75E-08	2.84E-08	3.27E-08	3.44E-08	3.17E-08	2.62E-08
1.6E+04	2.80E-08	2.98E-08	2.99E-08	3.04E-08	3.34E-08	3.43E-08	3.15E-08	2.61E-08
2.0E+04	2.59E-08	3.12E-08	3.12E-08	3.16E-08	3.38E-08	3.42E-08	3.13E-08	2.59E-08

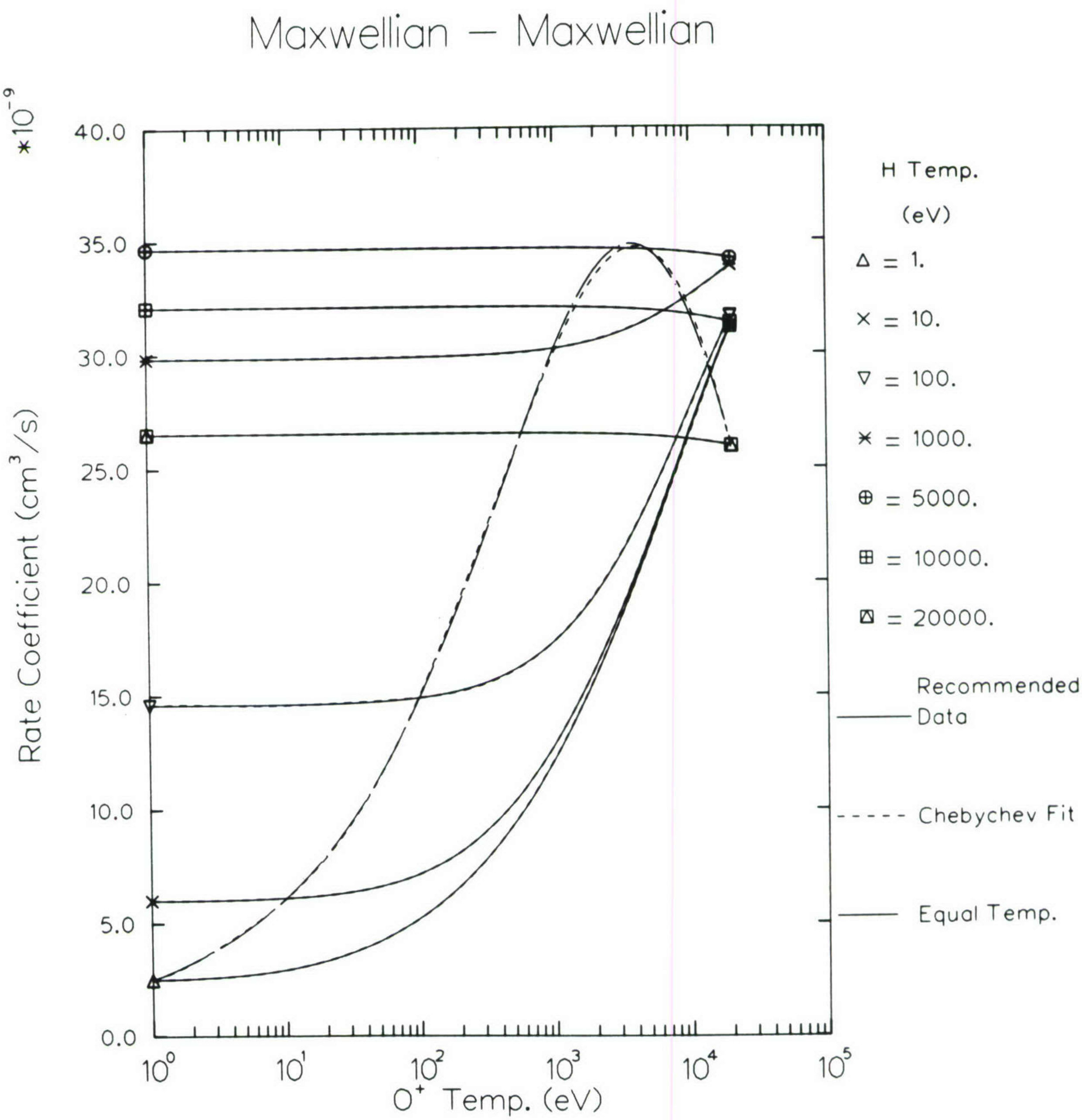
Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

Chebychev Fitting Parameters for Rate Coefficients

H Temp. (eV)	C1	C2	C3	C4	C5	C6	C7
1.	2.336E-08	1.377E-08	5.544E-09	8.272E-10	-2.865E-10	-2.152E-10	-6.919E-11
10.	2.690E-08	1.179E-08	5.560E-09	1.132E-09	-3.270E-10	-2.990E-10	-7.832E-11
100.	3.804E-08	7.367E-09	4.167E-09	1.408E-09	5.678E-11	-2.353E-10	-1.379E-10
1000.	6.147E-08	1.563E-09	1.005E-09	4.645E-10	1.318E-10	-8.514E-13	-2.696E-11
5000.	6.913E-08	-1.504E-10	-1.115E-10	-7.026E-11	-3.840E-11	-1.838E-11	-8.046E-12
10000.	6.387E-08	-2.465E-10	-1.765E-10	-1.039E-10	-5.116E-11	-2.128E-11	-7.683E-12
20000.	5.284E-08	-1.970E-10	-1.407E-10	-8.236E-11	-4.021E-11	-1.650E-11	-5.824E-12
Equal Temp.	3.513E-08	1.648E-08	-1.671E-09	-4.838E-09	-1.970E-09	-2.962E-11	1.931E-10

See appendix for Chebychev fit details.

$O^+ + H \rightarrow O + H^+$



Total Electron Capture Rate Coefficients for
$H + O^+ \rightarrow O + H^+$

Beam - Maxwellian Rate Coefficients (cm^3/s)

O^+ Temp. (eV)	H Energy (eV/amu) 10000.	20000.	40000.	70000.	100000.	200000.	500000.
1.0E+00	3.56E-08	2.99E-08	2.10E-08	1.26E-08	8.39E-09	2.25E-09	1.81E-10
1.1E+00	3.56E-08	2.99E-08	2.10E-08	1.26E-08	8.39E-09	2.25E-09	1.81E-10
1.6E+00	3.56E-08	2.99E-08	2.10E-08	1.26E-08	8.39E-09	2.25E-09	1.81E-10
3.2E+00	3.56E-08	2.99E-08	2.10E-08	1.26E-08	8.39E-09	2.25E-09	1.81E-10
6.4E+00	3.56E-08	2.99E-08	2.10E-08	1.26E-08	8.39E-09	2.25E-09	1.81E-10
1.1E+01	3.56E-08	2.99E-08	2.10E-08	1.26E-08	8.39E-09	2.25E-09	1.81E-10
1.6E+01	3.56E-08	2.99E-08	2.10E-08	1.26E-08	8.39E-09	2.25E-09	1.81E-10
3.2E+01	3.56E-08	2.99E-08	2.10E-08	1.26E-08	8.39E-09	2.25E-09	1.81E-10
6.4E+01	3.56E-08	2.98E-08	2.10E-08	1.26E-08	8.38E-09	2.25E-09	1.81E-10
1.1E+02	3.56E-08	2.98E-08	2.10E-08	1.26E-08	8.38E-09	2.25E-09	1.81E-10
1.6E+02	3.56E-08	2.98E-08	2.10E-08	1.26E-08	8.38E-09	2.25E-09	1.81E-10
3.2E+02	3.55E-08	2.98E-08	2.10E-08	1.26E-08	8.38E-09	2.25E-09	1.81E-10
6.4E+02	3.55E-08	2.98E-08	2.10E-08	1.26E-08	8.37E-09	2.25E-09	1.81E-10
1.1E+03	3.55E-08	2.98E-08	2.09E-08	1.26E-08	8.37E-09	2.25E-09	1.81E-10
1.6E+03	3.54E-08	2.97E-08	2.09E-08	1.26E-08	8.36E-09	2.25E-09	1.81E-10
3.2E+03	3.53E-08	2.96E-08	2.09E-08	1.26E-08	8.35E-09	2.25E-09	1.81E-10
6.4E+03	3.51E-08	2.95E-08	2.08E-08	1.26E-08	8.34E-09	2.26E-09	1.82E-10
1.1E+04	3.48E-08	2.93E-08	2.07E-08	1.26E-08	8.33E-09	2.27E-09	1.82E-10
1.6E+04	3.45E-08	2.91E-08	2.06E-08	1.26E-08	8.32E-09	2.28E-09	1.83E-10
2.0E+04	3.42E-08	2.90E-08	2.06E-08	1.26E-08	8.32E-09	2.29E-09	1.83E-10

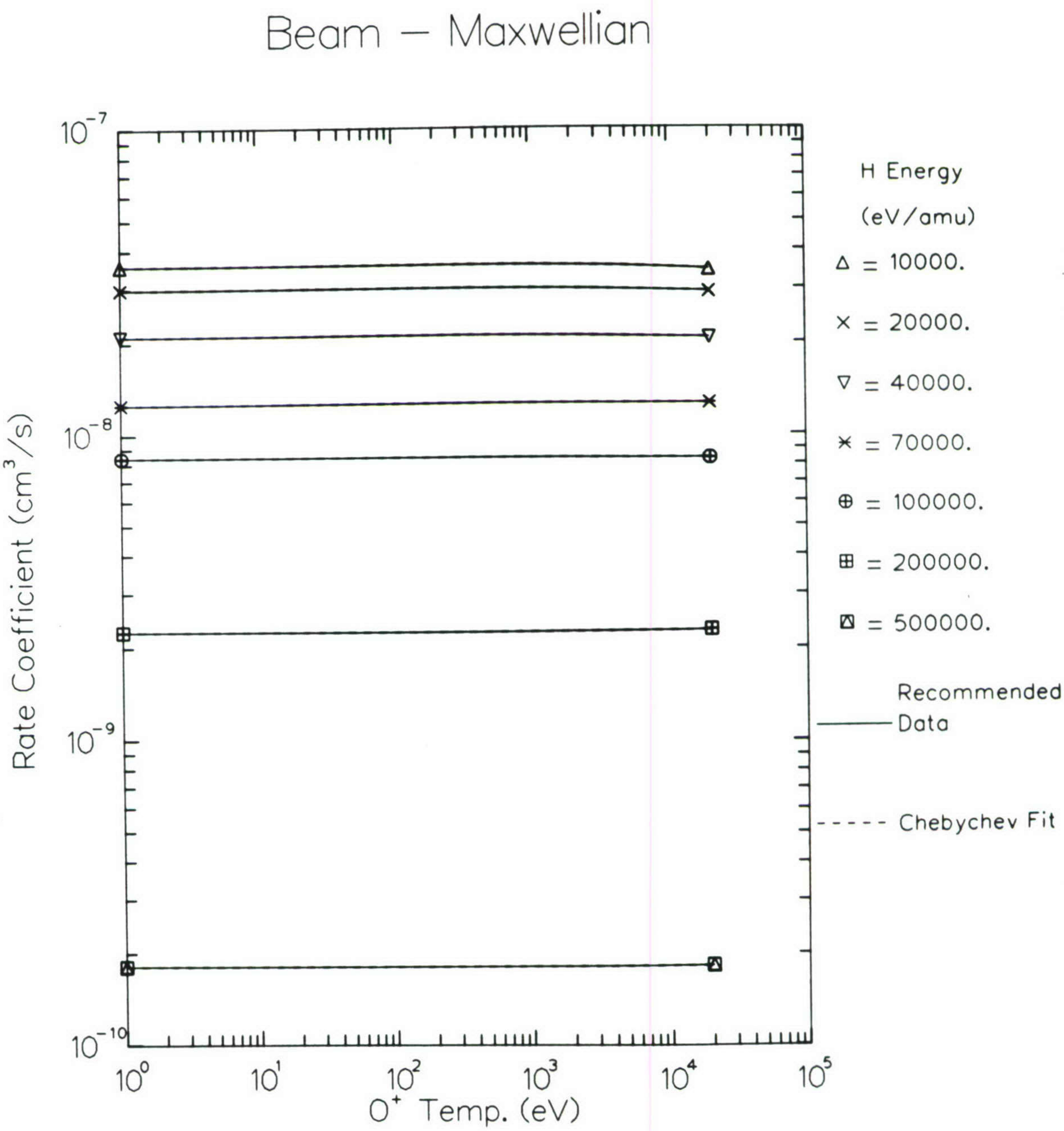
Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

Chebychev Fitting Parameters for Rate Coefficients

H Energy (eV/amu)	C1	C2	C3	C4	C5	C6	C7
10000.	7.063E-08	-4.407E-10	-3.112E-10	-1.789E-10	-8.787E-11	-3.910E-11	-1.636E-11
20000.	5.936E-08	-3.085E-10	-1.975E-10	-1.021E-10	-4.492E-11	-1.802E-11	-7.138E-12
40000.	4.180E-08	-1.709E-10	-1.027E-10	-4.871E-11	-1.855E-11	-5.301E-12	-6.287E-13
70000.	2.516E-08	1.887E-11	8.948E-12	3.033E-12	1.015E-12	6.467E-13	8.250E-13
100000.	1.673E-08	-3.336E-11	-1.519E-11	-3.985E-12	2.623E-14	6.997E-13	3.705E-13
200000.	4.510E-09	1.226E-11	9.304E-12	5.765E-12	3.005E-12	1.336E-12	4.979E-13
500000.	3.627E-10	6.698E-13	4.814E-13	2.897E-13	1.514E-13	7.165E-14	3.541E-14

See appendix for Chebychev fit details.

$H + O^{+} \to O + H^{+}$



Beam — Maxwellian
Rate Coefficient (cm^3/s)
O$^+$ Temp. (eV)
10^{-7}
10^{-8}
10^{-9}
10^{-10}
10^0
10^1
10^2
10^3
10^4
10^5
H Energy
(eV/amu)
△ = 10000.
× = 20000.
▽ = 40000.
✱ = 70000.
⊕ = 100000.
⊞ = 200000.
⊠ = 500000.
Recommended Data
Chebychev Fit

Total Electron Capture Cross Sections for
$O^{2+} + H \rightarrow O^{+} + H^{+}$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
2.0E+00	1.96E+06	8.50E-16
4.0E+00	2.78E+06	7.97E-16
7.0E+00	3.68E+06	7.59E-16
1.0E+01	4.39E+06	7.23E-16
2.0E+01	6.21E+06	6.43E-16
4.0E+01	8.79E+06	5.51E-16
7.0E+01	1.16E+07	4.73E-16
1.0E+02	1.39E+07	4.26E-16
2.0E+02	1.96E+07	3.37E-16
4.0E+02	2.78E+07	2.54E-16
7.0E+02	3.68E+07	2.10E-16
1.0E+03	4.39E+07	1.97E-16
1.3E+03	4.91E+07	2.00E-16
2.0E+03	6.21E+07	2.35E-16
4.0E+03	8.79E+07	3.34E-16
7.0E+03	1.16E+08	4.35E-16
1.0E+04	1.39E+08	4.76E-16
2.0E+04	1.96E+08	5.07E-16
4.0E+04	2.78E+08	3.36E-16
7.0E+04	3.68E+08	1.34E-16
1.0E+05	4.39E+08	5.63E-17
2.0E+05	6.21E+08	6.26E-18

References: E.1, E.5, E.8, E.16, T.1, T.3, T.9

Accuracy: 35% for $1 \leq E$ (eV/amu) $< 2x10^2$; 25% for $2x10^2 \leq E$ (eV/amu) $\leq 1x10^5$; 30-40% for $E >$ $1x10^5$ eV/amu

Notes: (1) Calculations [T.3] indicate that the cross section continues to increase slowly for $E < 1$ eV/amu, at least down to 0.1 eV/amu, where its value is about $1.1x10^{-15}$ cm^2.
(2) In the region $E \lesssim 5x10^2$ eV/amu, capture dominantly goes to the O^+ ($2s2p^4$ ^4P) final state [T.3].

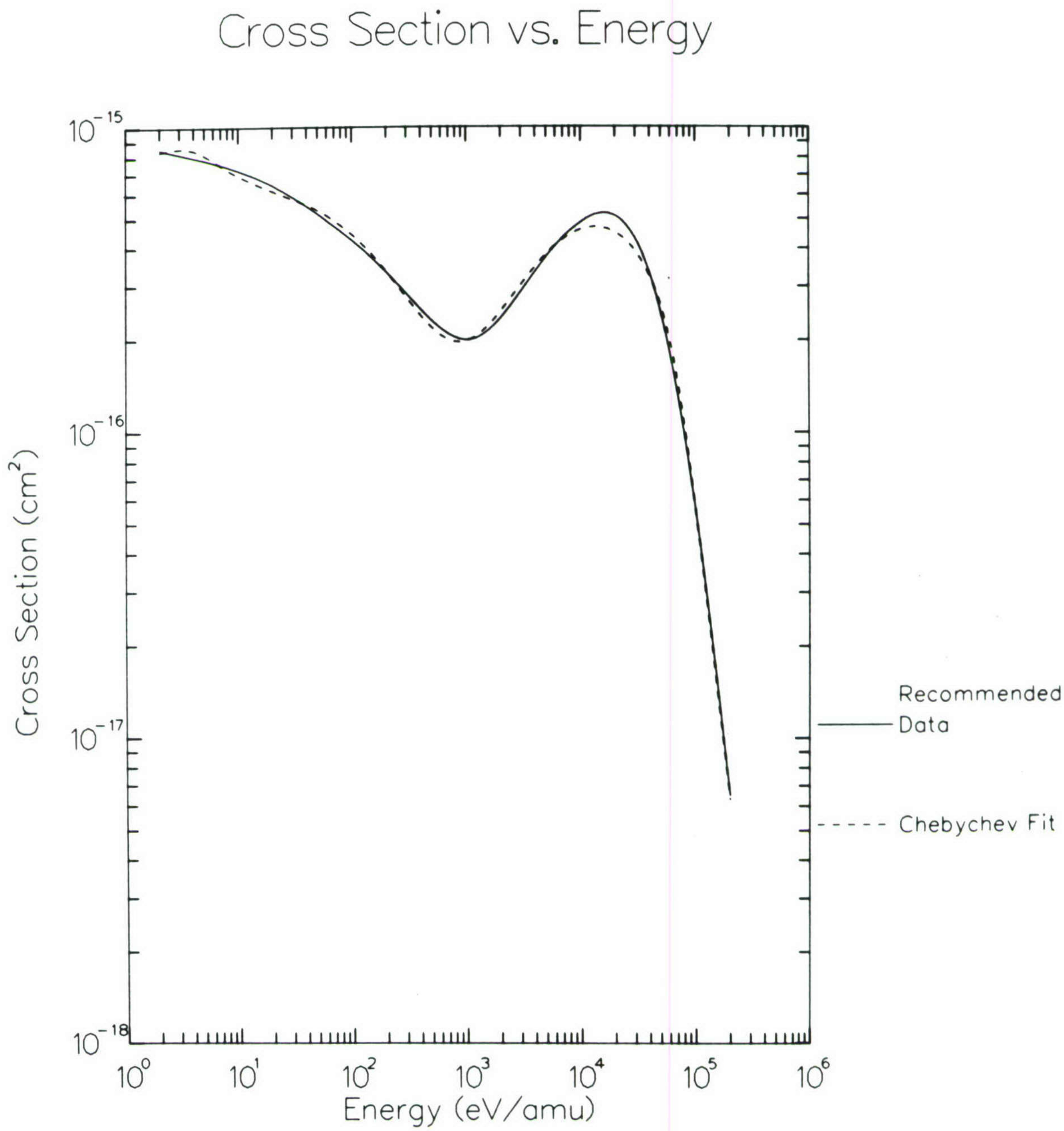
For Chebychev fits of the above cross sections it is necessary to use the following parameters.
E_{min} = 2.0E+00 eV/amu, E_{max} = 2.0E+05 eV/amu

Chebychev Fitting Parameters for Cross Sections

C1	C2	C3	C4	C5	C6	C7	C8	C9
8.548E-16	-3.748E-16	5.149E-17	-1.041E-16	-9.912E-17	1.903E-17	5.631E-17	4.623E-17	-1.609E-17

The fit represents the above cross sections with an rms deviation of 5.3%.
The maximum deviation is 14.5% at 7.0E+04 eV/amu.
See appendix for Chebychev fit details.

$O^{2+} + H \rightarrow O^{+} + H^{+}$



Total Electron Capture Rate Coefficients for
$O^{2+} + H \rightarrow O^{+} + H^{+}$

Maxwellian - Maxwellian Rate Coefficients (cm^3/s)

O^{2+} Temp. (eV)	Equal Temp.	H Temp. (eV) 1.	10.	100.	1000.	5000.	10000.	20000.
1.6E+00	1.69E-09	1.41E-09	3.31E-09	5.87E-09	1.25E-08	4.63E-08	6.71E-08	7.49E-08
3.2E+00	2.24E-09	1.47E-09	3.32E-09	5.87E-09	1.25E-08	4.63E-08	6.71E-08	7.49E-08
6.4E+00	2.90E-09	1.56E-09	3.34E-09	5.87E-09	1.25E-08	4.63E-08	6.71E-08	7.49E-08
1.1E+01	3.49E-09	1.69E-09	3.38E-09	5.88E-09	1.25E-08	4.63E-08	6.71E-08	7.49E-08
1.6E+01	3.89E-09	1.81E-09	3.41E-09	5.88E-09	1.25E-08	4.63E-08	6.71E-08	7.49E-08
3.2E+01	4.69E-09	2.13E-09	3.50E-09	5.89E-09	1.25E-08	4.63E-08	6.71E-08	7.49E-08
6.4E+01	5.47E-09	2.59E-09	3.67E-09	5.91E-09	1.26E-08	4.63E-08	6.71E-08	7.49E-08
1.1E+02	6.04E-09	3.06E-09	3.89E-09	5.94E-09	1.26E-08	4.63E-08	6.72E-08	7.49E-08
1.6E+02	6.40E-09	3.41E-09	4.08E-09	5.97E-09	1.26E-08	4.63E-08	6.72E-08	7.49E-08
3.2E+02	7.35E-09	4.13E-09	4.55E-09	6.05E-09	1.27E-08	4.64E-08	6.72E-08	7.49E-08
6.4E+02	9.73E-09	4.90E-09	5.13E-09	6.21E-09	1.29E-08	4.65E-08	6.72E-08	7.49E-08
1.1E+03	1.43E-08	5.51E-09	5.64E-09	6.40E-09	1.32E-08	4.67E-08	6.73E-08	7.49E-08
1.6E+03	1.93E-08	5.88E-09	5.97E-09	6.58E-09	1.34E-08	4.69E-08	6.74E-08	7.49E-08
3.2E+03	3.47E-08	6.58E-09	6.63E-09	7.12E-09	1.44E-08	4.75E-08	6.76E-08	7.48E-08
6.4E+03	5.61E-08	7.72E-09	7.77E-09	8.37E-09	1.63E-08	4.87E-08	6.81E-08	7.48E-08
1.1E+04	7.09E-08	9.90E-09	9.97E-09	1.07E-08	1.93E-08	5.05E-08	6.87E-08	7.47E-08
1.6E+04	7.50E-08	1.25E-08	1.26E-08	1.34E-08	2.22E-08	5.21E-08	6.93E-08	7.46E-08
2.0E+04	7.45E-08	1.49E-08	1.50E-08	1.58E-08	2.45E-08	5.34E-08	6.98E-08	7.45E-08

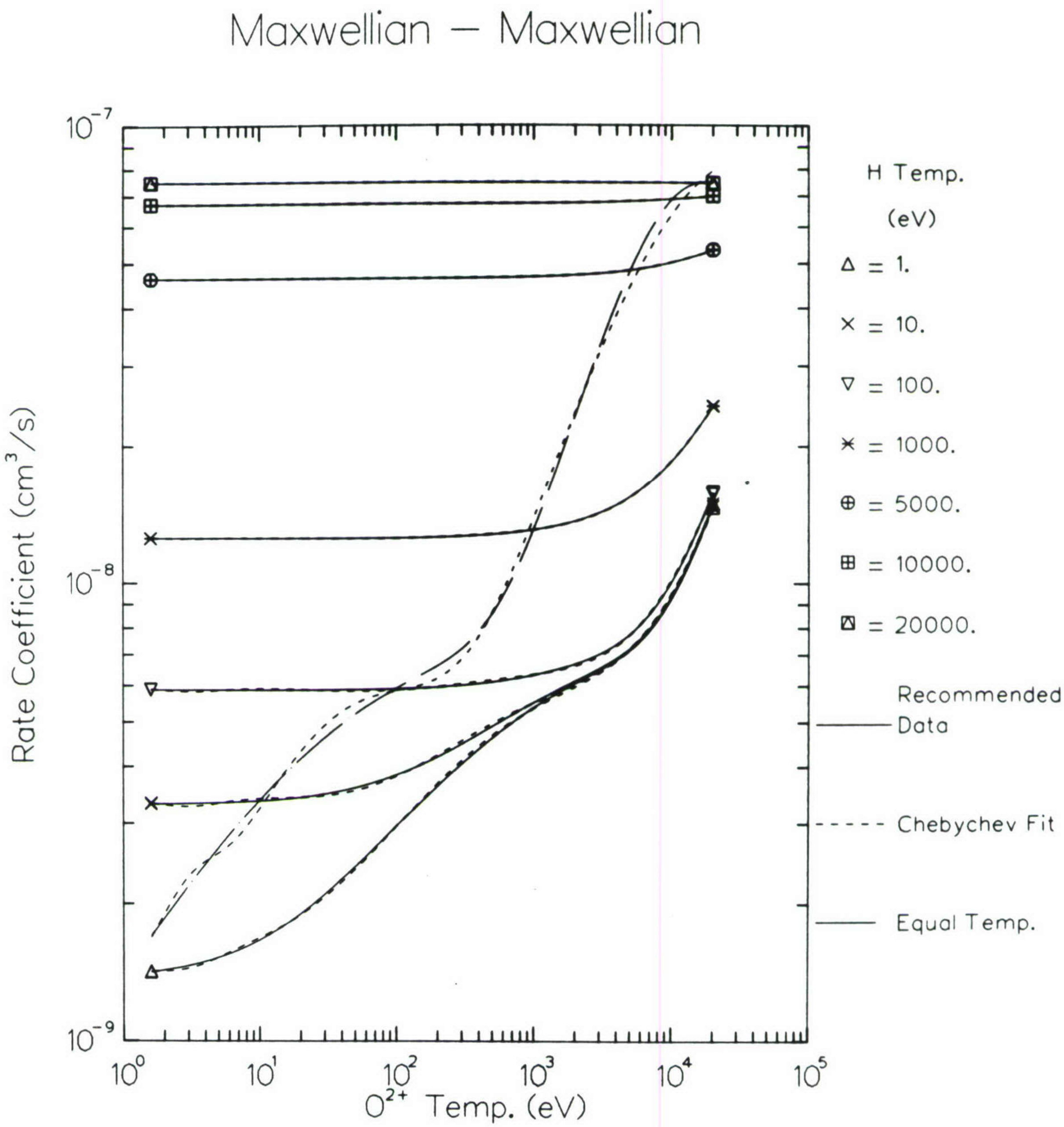
Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.6E+00 eV, E_{max} = 2.0E+04 eV

Chebychev Fitting Parameters for Rate Coefficients

H Temp. (eV)	C1	C2	C3	C4	C5	C6	C7
1.	1.019E-08	5.300E-09	2.068E-09	8.338E-10	6.944E-10	4.733E-10	1.673E-10
10.	1.193E-08	4.237E-09	2.234E-09	1.041E-09	6.480E-10	4.415E-10	2.036E-10
100.	1.522E-08	3.119E-09	2.243E-09	1.397E-09	7.772E-10	3.875E-10	1.632E-10
1000.	2.957E-08	4.040E-09	2.849E-09	1.642E-09	7.810E-10	3.069E-10	9.689E-11
5000.	9.532E-08	2.470E-09	1.709E-09	9.485E-10	4.256E-10	1.536E-10	4.298E-11
10000.	1.353E-07	9.323E-10	6.421E-10	3.526E-10	1.552E-10	5.401E-11	1.384E-11
20000.	1.497E-07	-1.103E-10	-8.005E-11	-4.934E-11	-2.614E-11	-1.211E-11	-5.231E-12
Equal Temp.	4.701E-08	3.423E-08	1.823E-08	6.676E-09	-2.058E-10	-2.132E-09	-1.083E-09

See appendix for Chebychev fit details.

$O^{2+} + H \rightarrow O^{+} + H^{+}$



Total Electron Capture Rate Coefficients for
$H + O^{2+} \rightarrow O^{+} + H^{+}$

Beam - Maxwellian Rate Coefficients (cm^3/s)

O^{2+} Temp. (eV)	H Energy (eV/amu) 10000.	20000.	40000.	70000.	100000.	200000.	500000.
1.6E+00	6.61E-08	9.96E-08	9.33E-08	4.92E-08	2.47E-08	3.89E-09	1.61E-10
3.2E+00	6.61E-08	9.96E-08	9.33E-08	4.92E-08	2.47E-08	3.89E-09	1.61E-10
6.4E+00	6.61E-08	9.95E-08	9.33E-08	4.92E-08	2.47E-08	3.89E-09	1.61E-10
1.1E+01	6.61E-08	9.95E-08	9.33E-08	4.92E-08	2.47E-08	3.89E-09	1.61E-10
1.6E+01	6.61E-08	9.95E-08	9.33E-08	4.92E-08	2.47E-08	3.89E-09	1.61E-10
3.2E+01	6.61E-08	9.95E-08	9.33E-08	4.92E-08	2.47E-08	3.89E-09	1.61E-10
6.4E+01	6.62E-08	9.94E-08	9.32E-08	4.92E-08	2.47E-08	3.89E-09	1.61E-10
1.1E+02	6.62E-08	9.93E-08	9.32E-08	4.92E-08	2.47E-08	3.89E-09	1.61E-10
1.6E+02	6.62E-08	9.93E-08	9.31E-08	4.92E-08	2.47E-08	3.89E-09	1.61E-10
3.2E+02	6.62E-08	9.91E-08	9.30E-08	4.92E-08	2.48E-08	3.90E-09	1.62E-10
6.4E+02	6.63E-08	9.89E-08	9.28E-08	4.92E-08	2.48E-08	3.90E-09	1.62E-10
1.1E+03	6.64E-08	9.87E-08	9.26E-08	4.92E-08	2.48E-08	3.91E-09	1.62E-10
1.6E+03	6.64E-08	9.85E-08	9.24E-08	4.92E-08	2.48E-08	3.91E-09	1.62E-10
3.2E+03	6.68E-08	9.78E-08	9.19E-08	4.92E-08	2.49E-08	3.93E-09	1.62E-10
6.4E+03	6.74E-08	9.70E-08	9.08E-08	4.92E-08	2.50E-08	3.96E-09	1.61E-10
1.1E+04	6.83E-08	9.60E-08	8.97E-08	4.92E-08	2.52E-08	4.01E-09	1.58E-10
1.6E+04	6.93E-08	9.49E-08	8.85E-08	4.92E-08	2.53E-08	4.06E-09	1.56E-10
2.0E+04	6.98E-08	9.44E-08	8.78E-08	4.92E-08	2.54E-08	4.10E-09	1.56E-10

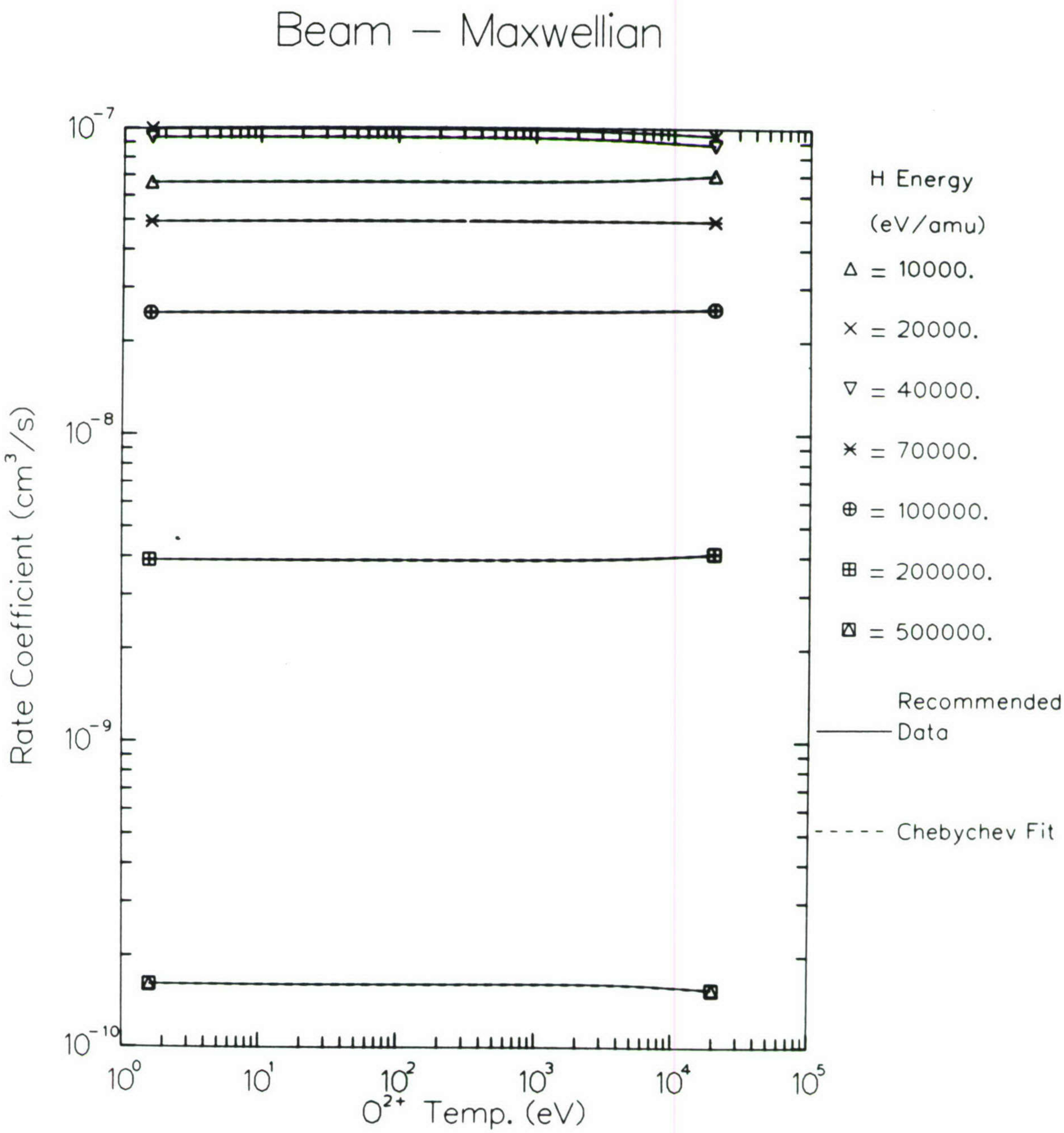
Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.6E+00 eV, E_{max} = 2.0E+04 eV

Chebychev Fitting Parameters for Rate Coefficients

H Energy (eV/amu)	C1	C2	C3	C4	C5	C6	C7
10000.	1.337E-07	1.286E-09	8.893E-10	4.992E-10	2.230E-10	7.158E-11	7.912E-12
20000.	1.966E-07	-2.082E-09	-1.141E-09	-4.832E-10	-1.694E-10	-5.359E-11	-1.713E-11
40000.	1.841E-07	-2.106E-09	-1.265E-09	-6.067E-10	-2.406E-10	-7.817E-11	-1.937E-11
70000.	9.847E-08	-2.142E-11	-1.434E-11	-9.215E-12	-5.550E-12	-2.543E-12	1.722E-14
100000.	4.974E-08	2.443E-10	1.618E-10	8.523E-11	3.594E-11	1.117E-11	5.012E-13
200000.	7.863E-09	7.313E-11	4.762E-11	2.563E-11	1.184E-11	4.755E-12	1.697E-12
500000.	3.212E-10	-1.594E-12	-1.566E-12	-1.234E-12	-7.357E-13	-2.701E-13	7.036E-14

See appendix for Chebychev fit details.

$H + O^{2+} -> O^{+} + H^{+}$


Beam – Maxwellian
Rate Coefficient (cm³/s)
10⁻⁷
10⁻⁸
10⁻⁹
10⁻¹⁰
10⁰
10¹
10²
10³
10⁴
10⁵
O²⁺ Temp. (eV)
H Energy
(eV/amu)
Δ = 10000.
× = 20000.
∇ = 40000.
✳ = 70000.
⊕ = 100000.
⊞ = 200000.
⊠ = 500000.
Recommended Data
Chebychev Fit

Total Electron Capture Cross Sections for
$O^{3+} + H \rightarrow O^{2+} + H^{+}$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
1.0E+00	1.39E+06	6.43E-15
2.0E+00	1.96E+06	6.34E-15
4.0E+00	2.78E+06	6.12E-15
7.0E+00	3.68E+06	5.42E-15
1.0E+01	4.39E+06	4.95E-15
2.0E+01	6.21E+06	3.72E-15
4.0E+01	8.79E+06	3.01E-15
7.0E+01	1.16E+07	3.31E-15
1.0E+02	1.39E+07	3.33E-15
2.0E+02	1.96E+07	2.91E-15
4.0E+02	2.78E+07	2.40E-15
7.0E+02	3.68E+07	2.53E-15
1.0E+03	4.39E+07	2.56E-15
1.3E+03	4.91E+07	2.50E-15
2.0E+03	6.21E+07	2.43E-15
4.0E+03	8.79E+07	2.24E-15
7.0E+03	1.16E+08	1.99E-15
1.0E+04	1.39E+08	1.85E-15
2.0E+04	1.96E+08	1.56E-15
4.0E+04	2.78E+08	1.00E-15
7.0E+04	3.68E+08	3.56E-16
1.0E+05	4.39E+08	1.20E-16
2.0E+05	6.21E+08	7.43E-18
2.5E+05	6.94E+08	2.17E-18

References: E.1, E.8, E.16, E.17, T.1, T.8, T.9, T.30, T.31

Accuracy: 30% for $1 \lesssim E$(eV/amu) < 40; 20% for $40 \lesssim E$(eV/amu) $\lesssim 1.2\text{x}10^5$; 30-40% for $E > 1.2\text{x}10^5$ eV/amu

Notes: (1) For E < 1 eV/amu the cross section continues to be energy-independent down to at least 0.2 eV/amu [T.3], [T.31].
(2) In the region $0.2 \lesssim E$(eV/amu) $\lesssim 5\text{x}10^3$, the predominantly populated final states are O^{2+} ($2s^2$ 2p3p ^3D), O^{2+}($2s^2$ 2p3p ^1P) and O^{2+}($2s^2$ 2p3p ^3S), with a prevailing capture to the ^3D state [T.3], [T.30].

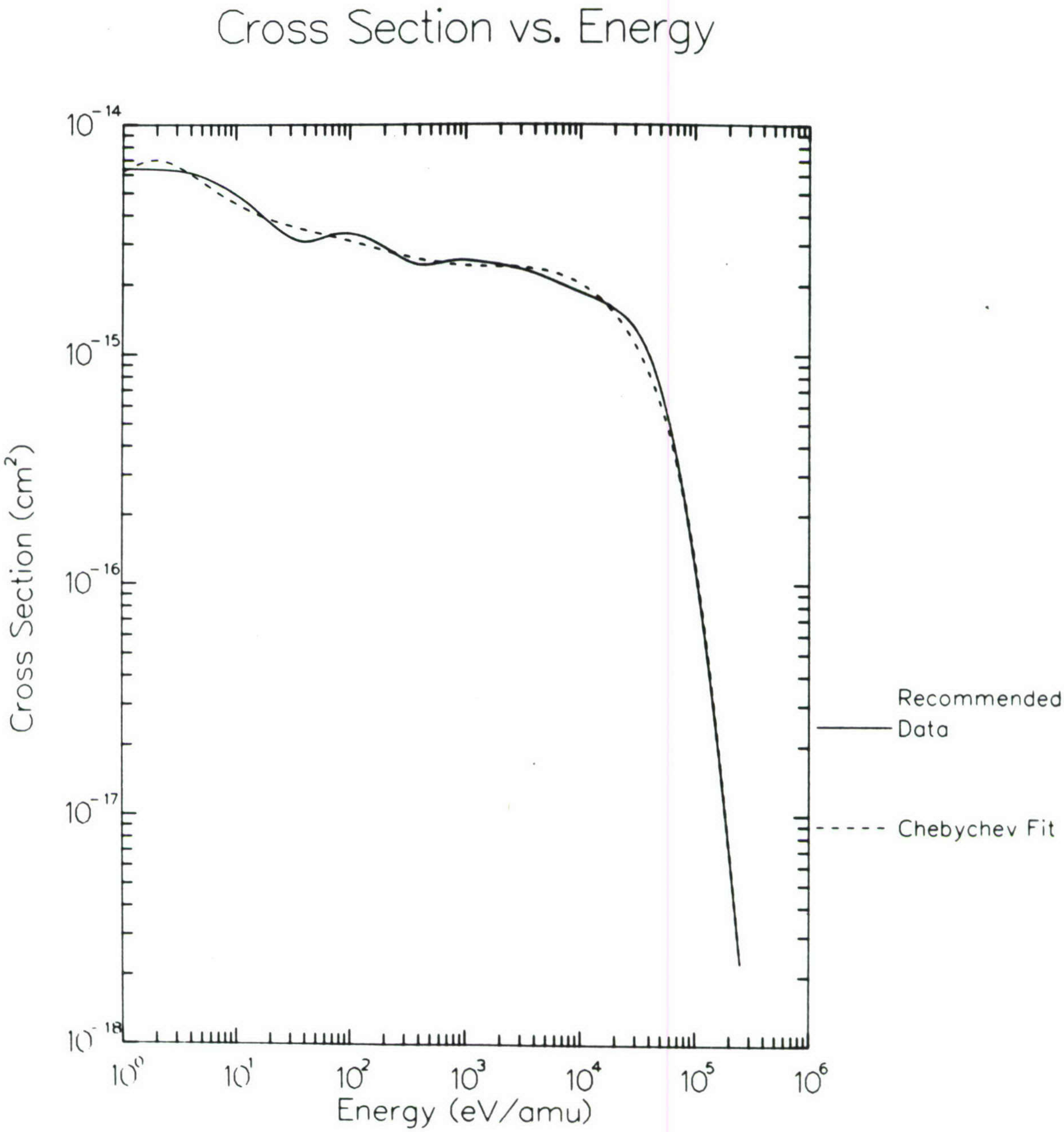
For Chebychev fits of the above cross sections it is necessary to use the following parameters.
E_{min} = 1.0E+00 eV/amu, E_{max} = 2.5E+05 eV/amu

Chebychev Fitting Parameters for Cross Sections

C1	C2	C3	C4	C5	C6	C7	C8	C9
6.121E-15	-3.313E-15	4.162E-16	-4.247E-16	-9.860E-17	4.338E-16	-1.320E-16	2.204E-16	-1.609E-16

The fit represents the above cross sections with an rms deviation of 7.6%.
The maximum deviation is 14.8% at 4.0E+01 eV/amu.
See appendix for Chebychev fit details.

$O^{3+} + H \rightarrow O^{2+} + H^{+}$



Total Electron Capture Rate Coefficients for
$O^{3+} + H \rightarrow O^{2+} + H^+$

Maxwellian - Maxwellian Rate Coefficients (cm^3/s)

O^{3+} Temp. (eV)	Equal Temp.	H Temp. (eV) 1.	10.	100.	1000.	5000.	10000.	20000.
1.6E+00	1.25E-08	1.03E-08	2.11E-08	4.68E-08	1.20E-07	2.15E-07	2.49E-07	2.45E-07
3.2E+00	1.61E-08	1.07E-08	2.12E-08	4.68E-08	1.20E-07	2.15E-07	2.49E-07	2.45E-07
6.4E+00	1.93E-08	1.15E-08	2.13E-08	4.68E-08	1.20E-07	2.15E-07	2.49E-07	2.45E-07
1.1E+01	2.19E-08	1.25E-08	2.14E-08	4.69E-08	1.20E-07	2.15E-07	2.49E-07	2.45E-07
1.6E+01	2.41E-08	1.33E-08	2.15E-08	4.69E-08	1.20E-07	2.15E-07	2.49E-07	2.45E-07
3.2E+01	3.09E-08	1.54E-08	2.20E-08	4.71E-08	1.20E-07	2.15E-07	2.49E-07	2.45E-07
6.4E+01	4.06E-08	1.79E-08	2.28E-08	4.74E-08	1.21E-07	2.15E-07	2.49E-07	2.45E-07
1.1E+02	4.97E-08	2.01E-08	2.41E-08	4.79E-08	1.21E-07	2.15E-07	2.49E-07	2.45E-07
1.6E+02	5.66E-08	2.15E-08	2.54E-08	4.84E-08	1.21E-07	2.15E-07	2.49E-07	2.45E-07
3.2E+02	7.49E-08	2.58E-08	2.94E-08	4.99E-08	1.21E-07	2.15E-07	2.49E-07	2.45E-07
6.4E+02	1.02E-07	3.33E-08	3.61E-08	5.27E-08	1.22E-07	2.15E-07	2.49E-07	2.45E-07
1.1E+03	1.29E-07	4.13E-08	4.32E-08	5.66E-08	1.24E-07	2.15E-07	2.49E-07	2.45E-07
1.6E+03	1.49E-07	4.69E-08	4.84E-08	6.02E-08	1.25E-07	2.16E-07	2.49E-07	2.45E-07
3.2E+03	1.91E-07	6.03E-08	6.13E-08	7.10E-08	1.30E-07	2.17E-07	2.50E-07	2.45E-07
6.4E+03	2.32E-07	8.06E-08	8.14E-08	8.89E-08	1.38E-07	2.19E-07	2.50E-07	2.44E-07
1.1E+04	2.53E-07	1.03E-07	1.04E-07	1.09E-07	1.49E-07	2.22E-07	2.51E-07	2.43E-07
1.6E+04	2.51E-07	1.20E-07	1.21E-07	1.25E-07	1.58E-07	2.25E-07	2.52E-07	2.43E-07
2.0E+04	2.42E-07	1.32E-07	1.32E-07	1.36E-07	1.65E-07	2.28E-07	2.52E-07	2.42E-07

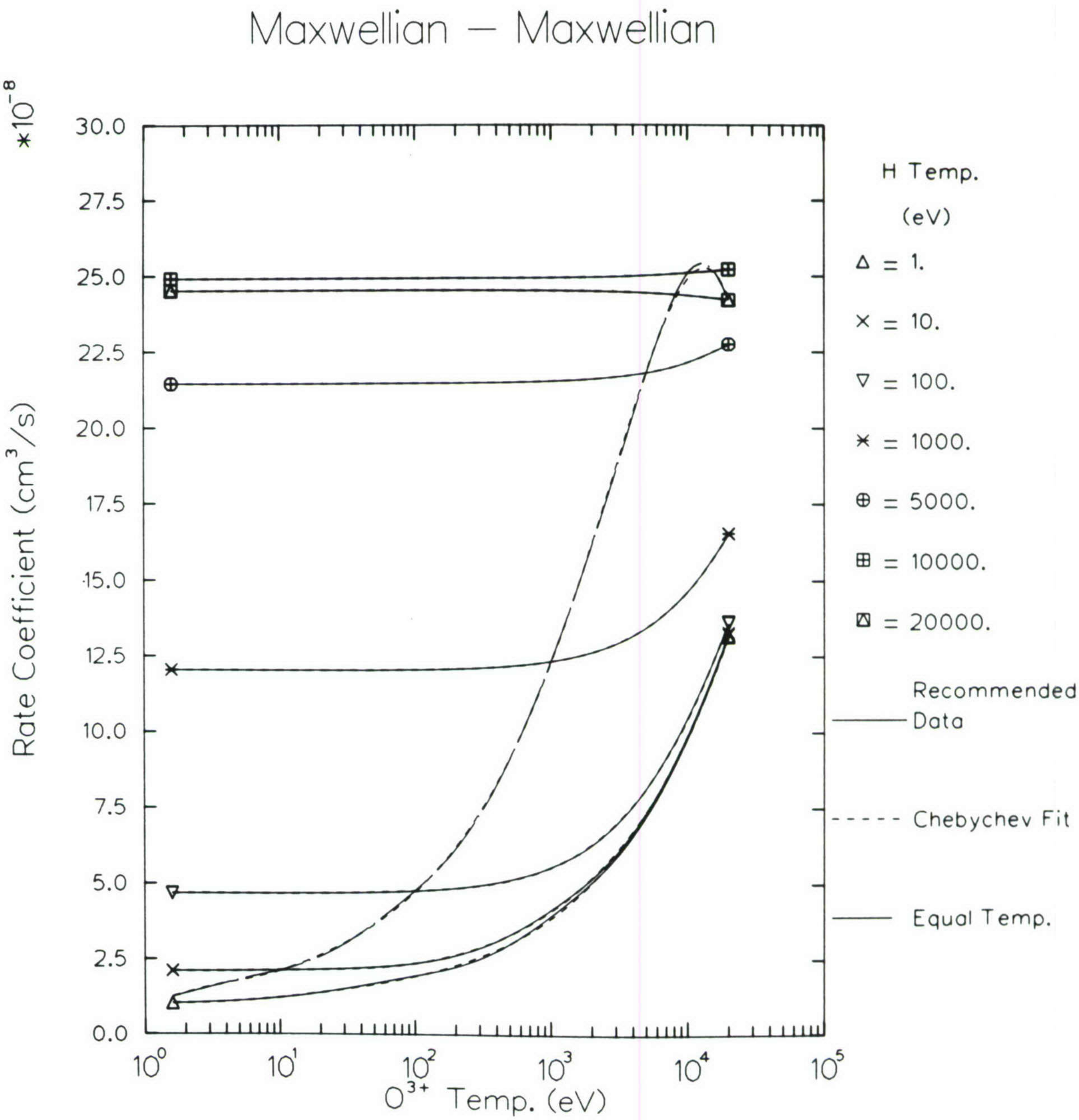
Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.6E+00 eV, E_{max} = 2.0E+04 eV

Chebychev Fitting Parameters for Rate Coefficients

H Temp. (eV)	C1	C2	C3	C4	C5	C6	C7
1.	8.933E-08	5.232E-08	2.428E-08	8.244E-09	2.056E-09	7.084E-11	-3.897E-11
10.	9.927E-08	4.662E-08	2.519E-08	8.794E-09	1.987E-09	6.045E-10	3.532E-10
100.	1.344E-07	3.487E-08	2.179E-08	9.798E-09	2.919E-09	3.263E-10	-1.931E-10
1000.	2.596E-07	1.640E-08	1.095E-08	5.613E-09	2.174E-09	5.809E-10	5.559E-11
5000.	4.342E-07	4.525E-09	3.112E-09	1.712E-09	7.626E-10	2.768E-10	8.136E-11
10000.	4.995E-07	1.091E-09	7.391E-10	3.900E-10	1.585E-10	4.613E-11	5.331E-12
20000.	4.892E-07	-1.029E-09	-7.272E-10	-4.237E-10	-2.066E-10	-8.566E-11	-3.170E-11
Equal Temp.	2.125E-07	1.284E-07	3.651E-08	-6.258E-09	-1.267E-08	-6.829E-09	-2.314E-09

See appendix for Chebychev fit details.

$O^{3+} + H \rightarrow O^{2+} + H^{+}$



Total Electron Capture Rate Coefficients for
$H + O^{3+} \rightarrow O^{2+} + H^+$

Beam - Maxwellian Rate Coefficients (cm^3/s)

O^{3+} Temp. (eV)	H Energy (eV/amu) 10000.	20000.	40000.	70000.	100000.	200000.	500000.
1.6E+00	2.57E-07	3.06E-07	2.78E-07	1.31E-07	5.27E-08	4.61E-09	9.26E-11
3.2E+00	2.57E-07	3.06E-07	2.78E-07	1.31E-07	5.27E-08	4.61E-09	9.26E-11
6.4E+00	2.57E-07	3.06E-07	2.78E-07	1.31E-07	5.27E-08	4.61E-09	9.26E-11
1.1E+01	2.57E-07	3.06E-07	2.78E-07	1.31E-07	5.27E-08	4.61E-09	9.26E-11
1.6E+01	2.57E-07	3.06E-07	2.77E-07	1.31E-07	5.27E-08	4.61E-09	9.26E-11
3.2E+01	2.57E-07	3.06E-07	2.77E-07	1.31E-07	5.27E-08	4.61E-09	9.26E-11
6.4E+01	2.57E-07	3.06E-07	2.77E-07	1.31E-07	5.27E-08	4.61E-09	9.26E-11
1.1E+02	2.57E-07	3.06E-07	2.77E-07	1.31E-07	5.28E-08	4.61E-09	9.26E-11
1.6E+02	2.57E-07	3.06E-07	2.77E-07	1.31E-07	5.28E-08	4.61E-09	9.27E-11
3.2E+02	2.57E-07	3.05E-07	2.76E-07	1.31E-07	5.28E-08	4.61E-09	9.27E-11
6.4E+02	2.57E-07	3.05E-07	2.75E-07	1.31E-07	5.29E-08	4.61E-09	9.27E-11
1.1E+03	2.57E-07	3.04E-07	2.74E-07	1.30E-07	5.30E-08	4.61E-09	9.28E-11
1.6E+03	2.57E-07	3.04E-07	2.73E-07	1.30E-07	5.31E-08	4.62E-09	9.29E-11
3.2E+03	2.57E-07	3.02E-07	2.71E-07	1.30E-07	5.34E-08	4.64E-09	9.32E-11
6.4E+03	2.58E-07	3.01E-07	2.67E-07	1.30E-07	5.40E-08	4.69E-09	9.38E-11
1.1E+04	2.59E-07	2.99E-07	2.63E-07	1.30E-07	5.48E-08	4.78E-09	9.47E-11
1.6E+04	2.61E-07	2.96E-07	2.59E-07	1.30E-07	5.56E-08	4.87E-09	9.57E-11
2.0E+04	2.61E-07	2.95E-07	2.57E-07	1.30E-07	5.61E-08	4.94E-09	9.65E-11

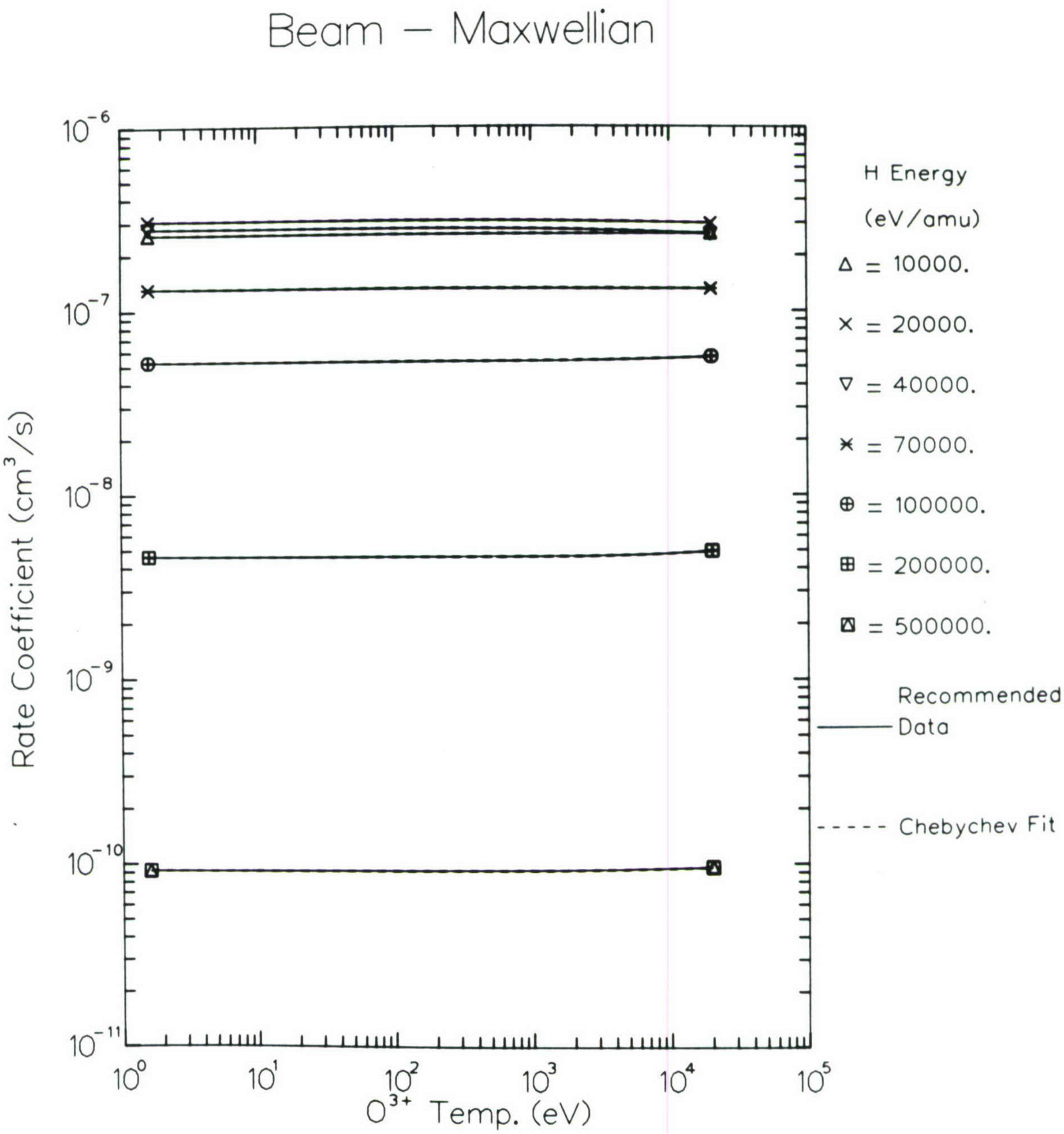
Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.6E+00 eV, E_{max} = 2.0E+04 eV

Chebychev Fitting Parameters for Rate Coefficients

H Energy (eV/amu)	C1	C2	C3	C4	C5	C6	C7
10000.	5.154E-07	1.358E-09	1.069E-09	6.264E-10	2.394E-10	1.816E-11	-5.816E-11
20000.	6.070E-07	-4.661E-09	-2.549E-09	-1.078E-09	-3.820E-10	-1.287E-10	-4.895E-11
40000.	5.451E-07	-8.292E-09	-4.594E-09	-1.980E-09	-6.969E-10	-1.986E-10	-4.058E-11
70000.	2.611E-07	-3.402E-10	-7.395E-11	3.332E-11	3.530E-11	1.608E-11	5.732E-12
100000.	1.068E-07	1.217E-09	8.043E-10	4.281E-10	1.863E-10	6.459E-11	1.418E-11
200000.	9.335E-09	1.013E-10	8.080E-11	5.161E-11	2.663E-11	1.137E-11	4.254E-12
500000.	1.867E-10	1.292E-12	9.100E-13	5.281E-13	2.568E-13	1.070E-13	4.134E-14

See appendix for Chebychev fit details.

$H + O^{3+} \rightarrow O^{2+} + H^{+}$



Total Electron Capture Cross Sections for
$O^{4+} + H \rightarrow O^{3+} + H^+$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
1.0E+00	1.39E+06	1.88E-16
2.0E+00	1.96E+06	1.94E-16
4.0E+00	2.78E+06	2.49E-16
7.0E+00	3.68E+06	3.99E-16
1.0E+01	4.39E+06	5.33E-16
2.0E+01	6.21E+06	9.63E-16
4.0E+01	8.79E+06	1.80E-15
7.0E+01	1.16E+07	2.90E-15
1.0E+02	1.39E+07	3.41E-15
1.3E+02	1.58E+07	3.76E-15
2.0E+02	1.96E+07	3.23E-15
4.0E+02	2.78E+07	2.35E-15
7.0E+02	3.68E+07	2.51E-15
1.0E+03	4.39E+07	2.70E-15
1.3E+03	4.91E+07	2.75E-15
2.0E+03	6.21E+07	2.80E-15
4.0E+03	8.79E+07	2.51E-15
7.0E+03	1.16E+08	2.39E-15
1.0E+04	1.39E+08	2.30E-15
2.0E+04	1.96E+08	1.99E-15
4.0E+04	2.78E+08	1.53E-15
7.0E+04	3.68E+08	6.35E-16
1.0E+05	4.39E+08	2.89E-16
2.0E+05	6.21E+08	1.91E-17
2.4E+05	6.80E+08	7.99E-18

References: E.1, E.5, E.8, E.17, T.1, T.8, T.9, T.32

Accuracy: 50% for E < 60 eV/amu; 25% for $60 \leq E(eV/amu) \leq 1.5x10^5$; 35% for $E > 1.5x10^5$ eV/amu

Notes: (1) In the region $3 \leq E(eV/amu) < 70$ where no cross section data exist, we have made an interpolation, to which we assigned an accuracy of 50%.

(2) According to Ref. [T.32], the cross section for $E \leq 1$ eV/amu should increase smoothly, reaching a value of ~ $3.5x10^{-16}$ cm^2 at $E = 7x10^{-2}$ eV/amu. This behavior has been taken into account in the reaction-rate calculations.

(3) The increase of cross section in the region below ~ 1.5 eV/amu is due to capture to the n=3 levels.

For Chebychev fits of the above cross sections it is necessary to use the following parameters.
E_{min} = 1.0E+00 eV/amu, E_{max} = 2.4E+05 eV/amu

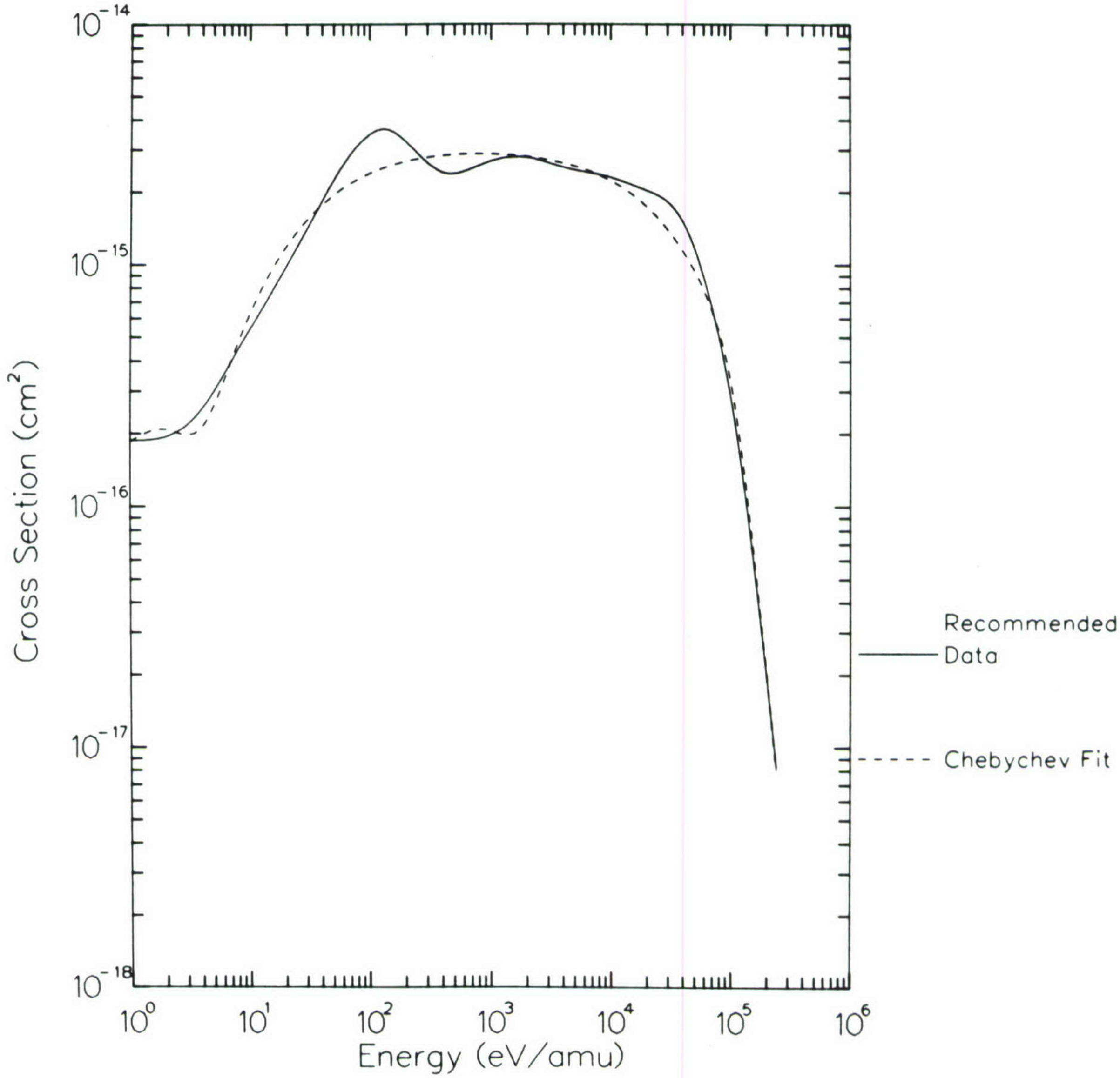
Chebychev Fitting Parameters for Cross Sections

C1	C2	C3	C4	C5	C6	C7	C8	C9
2.293E-15	1.550E-16	-1.406E-15	-3.335E-16	3.669E-16	2.569E-18	2.696E-17	8.775E-17	-3.847E-17

The fit represents the above cross sections with an rms deviation of 15.5%.
The maximum deviation is 21.4% at 2.0E+01 eV/amu.
See appendix for Chebychev fit details.

$O^{4+} + H \rightarrow O^{3+} + H^{+}$

Cross Section vs. Energy



Total Electron Capture Rate Coefficients for
$O^{4+} + H \rightarrow O^{3+} + H^{+}$

Maxwellian - Maxwellian Rate Coefficients (cm^3/s)

O^{4+} Temp. (eV)	Equal Temp.	H Temp. (eV) 1.	10.	100.	1000.	5000.	10000.	20000.
1.0E+00	3.50E-10	3.50E-10	4.74E-09	4.60E-08	1.32E-07	2.58E-07	3.17E-07	3.36E-07
1.1E+00	3.80E-10	3.51E-10	4.75E-09	4.60E-08	1.32E-07	2.58E-07	3.17E-07	3.36E-07
1.6E+00	5.19E-10	3.58E-10	4.77E-09	4.60E-08	1.32E-07	2.58E-07	3.17E-07	3.36E-07
3.2E+00	1.13E-09	3.83E-10	4.83E-09	4.61E-08	1.32E-07	2.58E-07	3.17E-07	3.36E-07
6.4E+00	2.79E-09	4.34E-10	4.96E-09	4.61E-08	1.32E-07	2.58E-07	3.17E-07	3.36E-07
1.1E+01	5.95E-09	5.19E-10	5.16E-09	4.62E-08	1.32E-07	2.58E-07	3.17E-07	3.36E-07
1.6E+01	9.55E-09	6.11E-10	5.35E-09	4.62E-08	1.32E-07	2.58E-07	3.17E-07	3.36E-07
3.2E+01	2.14E-08	9.70E-10	6.02E-09	4.64E-08	1.32E-07	2.58E-07	3.17E-07	3.36E-07
6.4E+01	3.75E-08	1.85E-09	7.40E-09	4.69E-08	1.33E-07	2.58E-07	3.17E-07	3.36E-07
1.1E+02	4.97E-08	3.47E-09	9.55E-09	4.75E-08	1.33E-07	2.58E-07	3.17E-07	3.36E-07
1.6E+02	5.73E-08	5.35E-09	1.17E-08	4.80E-08	1.33E-07	2.58E-07	3.17E-07	3.36E-07
3.2E+02	7.73E-08	1.25E-08	1.88E-08	4.99E-08	1.34E-07	2.58E-07	3.17E-07	3.36E-07
6.4E+02	1.09E-07	2.56E-08	3.02E-08	5.31E-08	1.35E-07	2.59E-07	3.17E-07	3.36E-07
1.1E+03	1.44E-07	3.85E-08	4.12E-08	5.73E-08	1.37E-07	2.59E-07	3.18E-07	3.36E-07
1.6E+03	1.68E-07	4.62E-08	4.80E-08	6.12E-08	1.38E-07	2.60E-07	3.18E-07	3.36E-07
2.1E+03	1.88E-07	5.17E-08	5.31E-08	6.48E-08	1.40E-07	2.60E-07	3.18E-07	3.36E-07
3.2E+03	2.24E-07	6.13E-08	6.24E-08	7.29E-08	1.44E-07	2.62E-07	3.18E-07	3.36E-07
6.4E+03	2.86E-07	8.38E-08	8.47E-08	9.36E-08	1.55E-07	2.65E-07	3.20E-07	3.36E-07
1.1E+04	3.28E-07	1.11E-07	1.12E-07	1.19E-07	1.68E-07	2.70E-07	3.22E-07	3.35E-07
1.6E+04	3.38E-07	1.32E-07	1.33E-07	1.38E-07	1.80E-07	2.75E-07	3.23E-07	3.35E-07
2.0E+04	3.34E-07	1.47E-07	1.47E-07	1.52E-07	1.89E-07	2.78E-07	3.25E-07	3.34E-07

Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

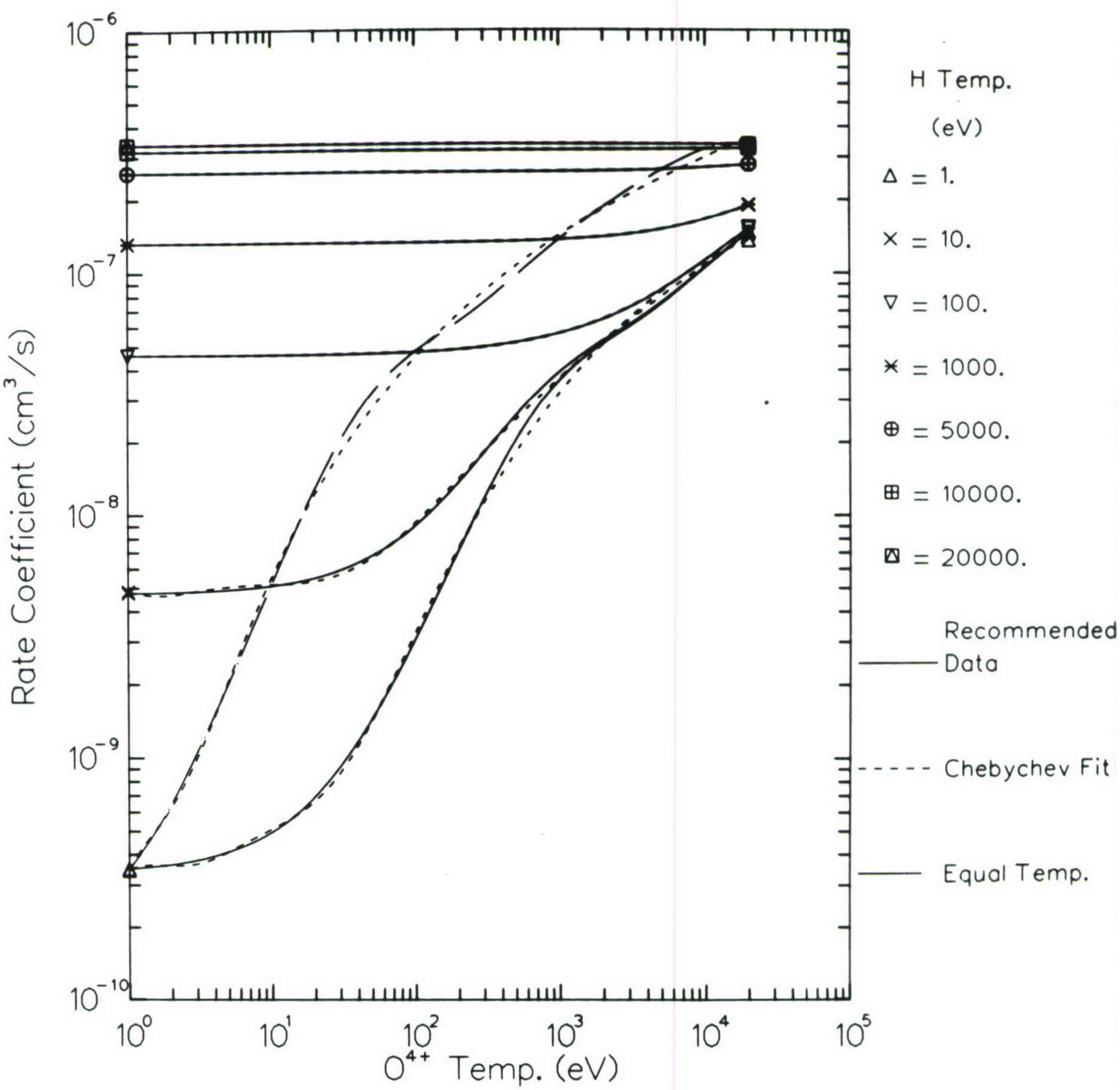
Chebychev Fitting Parameters for Rate Coefficients

H Temp. (eV)	C1	C2	C3	C4	C5	C6	C7
1.	7.732E-08	6.246E-08	3.218E-08	7.554E-09	-2.191E-09	-2.310E-09	-6.033E-10
10.	8.413E-08	6.037E-08	3.102E-08	8.828E-09	6.474E-10	3.891E-11	3.432E-10
100.	1.384E-07	3.995E-08	2.584E-08	1.260E-08	4.546E-09	1.075E-09	1.323E-11
1000.	2.877E-07	2.023E-08	1.384E-08	7.412E-09	3.074E-09	9.351E-10	1.602E-10
5000.	5.238E-07	6.894E-09	4.855E-09	2.760E-09	1.278E-09	4.796E-10	1.423E-10
10000.	6.371E-07	2.604E-09	1.828E-09	1.032E-09	4.710E-10	1.720E-10	4.758E-11
20000.	6.718E-07	-5.990E-10	-4.373E-10	-2.680E-10	-1.411E-10	-6.495E-11	-2.764E-11
Equal Temp.	2.383E-07	1.740E-07	6.215E-08	5.055E-09	-1.435E-09	7.294E-10	2.705E-10

See appendix for Chebychev fit details.

$O^{4+} + H \rightarrow O^{3+} + H^{+}$

Maxwellian — Maxwellian



Total Electron Capture Rate Coefficients for
$H + O^{4+} \rightarrow O^{3+} + H^{+}$

Beam - Maxwellian Rate Coefficients (cm^3/s)

O^{4+} Temp. (eV)	H Energy (eV/amu) 10000.	20000.	40000.	70000.	100000.	200000.	500000.
1.0E+00	3.19E-07	3.91E-07	4.25E-07	2.33E-07	1.27E-07	1.19E-08	1.07E-10
1.1E+00	3.19E-07	3.91E-07	4.25E-07	2.33E-07	1.27E-07	1.19E-08	1.07E-10
1.6E+00	3.19E-07	3.91E-07	4.25E-07	2.33E-07	1.27E-07	1.19E-08	1.07E-10
3.2E+00	3.19E-07	3.91E-07	4.25E-07	2.33E-07	1.27E-07	1.19E-08	1.07E-10
6.4E+00	3.19E-07	3.91E-07	4.25E-07	2.33E-07	1.27E-07	1.19E-08	1.07E-10
1.1E+01	3.19E-07	3.91E-07	4.24E-07	2.33E-07	1.27E-07	1.19E-08	1.07E-10
1.6E+01	3.19E-07	3.91E-07	4.24E-07	2.33E-07	1.27E-07	1.19E-08	1.07E-10
3.2E+01	3.19E-07	3.91E-07	4.24E-07	2.33E-07	1.27E-07	1.19E-08	1.07E-10
6.4E+01	3.19E-07	3.91E-07	4.24E-07	2.34E-07	1.27E-07	1.19E-08	1.07E-10
1.1E+02	3.19E-07	3.91E-07	4.23E-07	2.34E-07	1.27E-07	1.19E-08	1.07E-10
1.6E+02	3.19E-07	3.91E-07	4.23E-07	2.34E-07	1.27E-07	1.19E-08	1.07E-10
3.2E+02	3.19E-07	3.91E-07	4.22E-07	2.34E-07	1.27E-07	1.19E-08	1.07E-10
6.4E+02	3.19E-07	3.90E-07	4.20E-07	2.34E-07	1.27E-07	1.19E-08	1.07E-10
1.1E+03	3.19E-07	3.91E-07	4.18E-07	2.34E-07	1.26E-07	1.20E-08	1.07E-10
1.6E+03	3.19E-07	3.91E-07	4.17E-07	2.34E-07	1.26E-07	1.20E-08	1.07E-10
2.1E+03	3.20E-07	3.90E-07	4.16E-07	2.34E-07	1.26E-07	1.20E-08	1.07E-10
3.2E+03	3.20E-07	3.90E-07	4.13E-07	2.34E-07	1.26E-07	1.21E-08	1.08E-10
6.4E+03	3.21E-07	3.90E-07	4.07E-07	2.35E-07	1.26E-07	1.23E-08	1.09E-10
1.1E+04	3.22E-07	3.89E-07	4.00E-07	2.35E-07	1.26E-07	1.26E-08	1.11E-10
1.6E+04	3.24E-07	3.88E-07	3.94E-07	2.35E-07	1.26E-07	1.29E-08	1.13E-10
2.0E+04	3.25E-07	3.88E-07	3.90E-07	2.35E-07	1.26E-07	1.32E-08	1.15E-10

Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

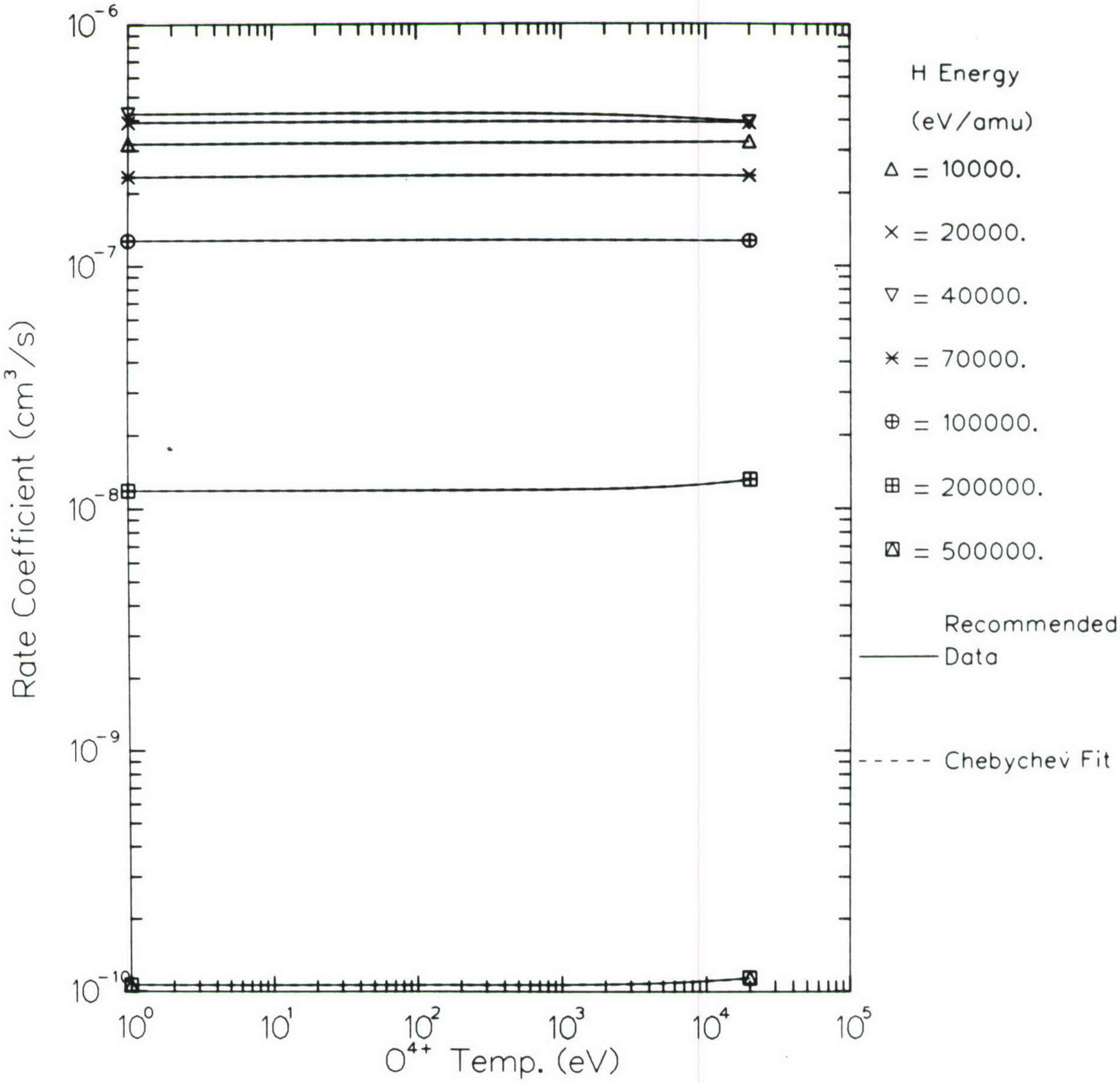
Chebychev Fitting Parameters for Rate Coefficients

H Energy (eV/amu)	C1	C2	C3	C4	C5	C6	C7
10000.	6.406E-07	1.594E-09	1.353E-09	9.080E-10	4.605E-10	1.651E-10	3.782E-11
20000.	7.804E-07	-1.188E-09	-7.075E-10	-3.180E-10	-1.156E-10	-4.323E-11	-1.819E-11
40000.	8.325E-07	-1.400E-08	-7.795E-09	-3.355E-09	-1.169E-09	-3.214E-10	-5.069E-11
70000.	4.677E-07	6.705E-10	2.349E-10	-2.826E-12	-6.060E-11	-4.829E-11	-2.702E-11
100000.	2.532E-07	-4.357E-10	-7.289E-11	8.089E-11	7.867E-11	3.864E-11	6.931E-12
200000.	2.425E-08	4.487E-10	3.014E-10	1.676E-10	7.995E-11	3.319E-11	1.229E-11
500000.	2.161E-10	2.578E-12	1.856E-12	1.107E-12	5.594E-13	2.440E-13	9.741E-14

See appendix for Chebychev fit details.

$H + O^{4+} \rightarrow O^{3+} + H^{+}$

Beam – Maxwellian



Total Electron Capture Cross Sections for
$O^{5+} + H \rightarrow O^{4+} + H^{+}$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
1.0E+01	4.39E+06	9.56E-15
2.0E+01	6.21E+06	8.78E-15
4.0E+01	8.79E+06	7.91E-15
7.0E+01	1.16E+07	6.89E-15
1.0E+02	1.39E+07	6.21E-15
2.0E+02	1.96E+07	4.54E-15
4.0E+02	2.78E+07	3.36E-15
7.0E+02	3.68E+07	3.11E-15
1.0E+03	4.39E+07	3.19E-15
1.3E+03	4.91E+07	3.20E-15
2.0E+03	6.21E+07	3.28E-15
4.0E+03	8.79E+07	3.25E-15
7.0E+03	1.16E+08	3.20E-15
1.0E+04	1.39E+08	3.08E-15
2.0E+04	1.96E+08	2.78E-15
4.0E+04	2.78E+08	2.14E-15
7.0E+04	3.68E+08	1.18E-15
1.0E+05	4.39E+08	5.31E-16
2.0E+05	6.21E+08	4.59E-17
4.0E+05	8.78E+08	2.47E-18
4.2E+05	8.96E+08	1.99E-18

References: E.1, E.7, E.8, E.17, E.18, T.1, T.8, T.9, T.33

Accuracy: 30% for $10 \leq E(eV/amu) < 70$; 20% for $70 \leq E(eV/amu) \leq 1.3x10^5$; 30% for $E > 1.5x10^5$ eV/amu

Notes: (1) The calculations within a restricted molecular orbital basis [T.33] indicate that the cross section continues to increase with decreasing collision energy below 10 eV/amu, having a value of $\sigma \simeq 1.7x10^{-14}$ cm^2 at 0.2 eV/amu. In calculations of the rate coefficients, this cross section behavior has been taken into account.
(2) Capture in this reaction dominantly goes to the n=3 shell of O^{4+} [T.33], but at very low energies n=4 states may also be appreciably populated.

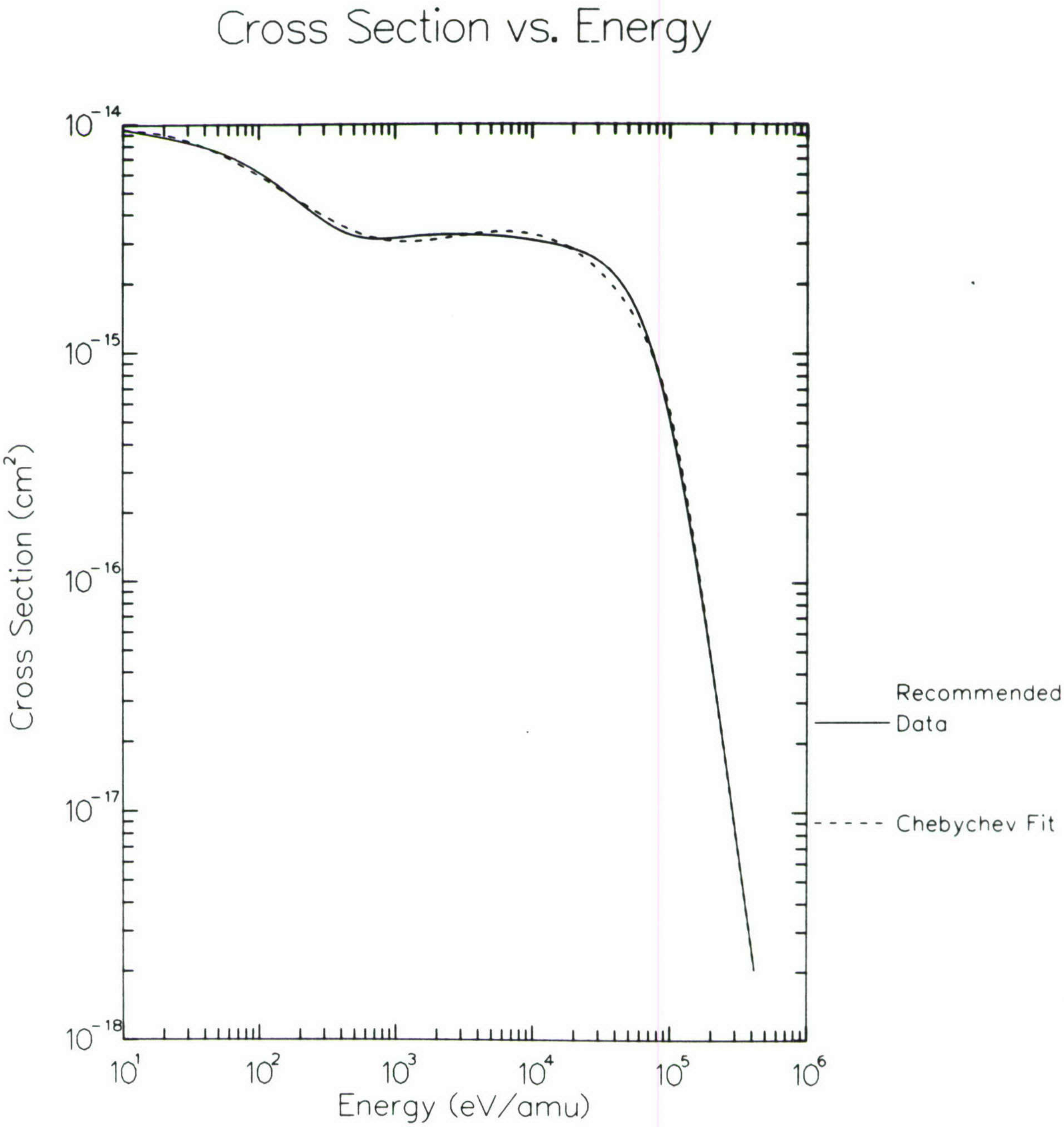
For Chebychev fits of the above cross sections it is necessary to use the following parameters.
E_{min} = 1.0E+01 eV/amu, E_{max} = 4.2E+05 eV/amu

Chebychev Fitting Parameters for Cross Sections

C1	C2	C3	C4	C5	C6	C7	C8	C9
8.158E-15	-4.651E-15	7.899E-16	-6.193E-16	-1.140E-16	6.616E-16	1.407E-17	-1.201E-16	-3.803E-17

The fit represents the above cross sections with an rms deviation of 5.3%.
The maximum deviation is 10.7% at 1.0E+05 eV/amu.
See appendix for Chebychev fit details.

$O^{5+} + H \rightarrow O^{4+} + H^{+}$



Total Electron Capture Rate Coefficients for
$O^{5+} + H \rightarrow O^{4+} + H^{+}$

Maxwellian - Maxwellian Rate Coefficients (cm^3/s)

O^{5+} Temp. (eV)	Equal Temp.	H Temp. (eV) 1.	10.	100.	1000.	5000.	10000.	20000.
3.2E+00	2.96E-08	1.92E-08	4.51E-08	8.20E-08	1.63E-07	3.41E-07	4.32E-07	4.78E-07
6.4E+00	3.88E-08	2.05E-08	4.55E-08	8.21E-08	1.63E-07	3.41E-07	4.32E-07	4.78E-07
1.1E+01	4.77E-08	2.23E-08	4.59E-08	8.21E-08	1.63E-07	3.41E-07	4.32E-07	4.78E-07
1.6E+01	5.40E-08	2.39E-08	4.64E-08	8.21E-08	1.63E-07	3.41E-07	4.32E-07	4.78E-07
3.2E+01	6.64E-08	2.82E-08	4.79E-08	8.23E-08	1.64E-07	3.41E-07	4.32E-07	4.78E-07
6.4E+01	7.72E-08	3.45E-08	5.05E-08	8.25E-08	1.64E-07	3.41E-07	4.32E-07	4.78E-07
1.1E+02	8.41E-08	4.13E-08	5.40E-08	8.28E-08	1.64E-07	3.41E-07	4.32E-07	4.78E-07
1.6E+02	8.90E-08	4.64E-08	5.69E-08	8.32E-08	1.64E-07	3.41E-07	4.32E-07	4.78E-07
3.2E+02	1.05E-07	5.78E-08	6.42E-08	8.42E-08	1.65E-07	3.41E-07	4.32E-07	4.78E-07
6.4E+02	1.37E-07	6.96E-08	7.28E-08	8.62E-08	1.66E-07	3.42E-07	4.33E-07	4.78E-07
1.1E+03	1.77E-07	7.77E-08	7.93E-08	8.90E-08	1.69E-07	3.42E-07	4.33E-07	4.78E-07
1.6E+03	2.10E-07	8.21E-08	8.32E-08	9.17E-08	1.71E-07	3.43E-07	4.33E-07	4.78E-07
3.2E+03	2.89E-07	9.18E-08	9.26E-08	1.01E-07	1.78E-07	3.46E-07	4.34E-07	4.78E-07
6.4E+03	3.83E-07	1.11E-07	1.12E-07	1.20E-07	1.92E-07	3.51E-07	4.37E-07	4.78E-07
1.1E+04	4.51E-07	1.39E-07	1.40E-07	1.47E-07	2.10E-07	3.58E-07	4.40E-07	4.78E-07
1.6E+04	4.76E-07	1.63E-07	1.64E-07	1.71E-07	2.27E-07	3.66E-07	4.43E-07	4.78E-07
2.0E+04	4.78E-07	1.82E-07	1.82E-07	1.88E-07	2.40E-07	3.71E-07	4.45E-07	4.78E-07

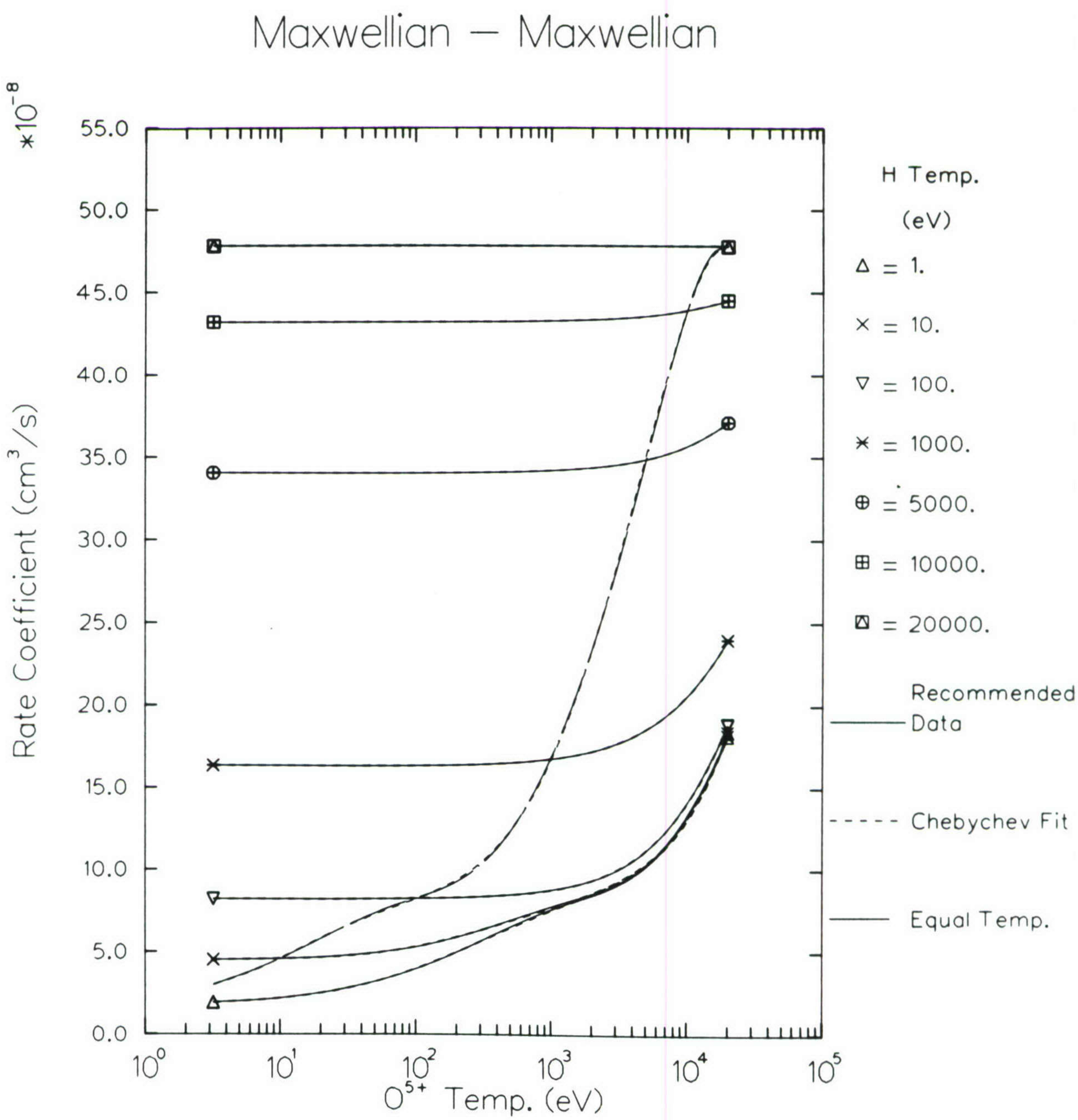
Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 3.2E+00 eV, E_{max} = 2.0E+04 eV

Chebychev Fitting Parameters for Rate Coefficients

H Temp. (eV)	C1	C2	C3	C4	C5	C6	C7
1.	1.422E-07	7.101E-08	2.291E-08	7.390E-09	6.688E-09	4.225E-09	1.086E-09
10.	1.649E-07	5.652E-08	2.557E-08	9.631E-09	5.799E-09	3.534E-09	9.498E-10
100.	2.086E-07	3.864E-08	2.569E-08	1.333E-08	5.416E-09	1.570E-09	1.405E-10
1000.	3.591E-07	2.798E-08	1.839E-08	9.326E-09	3.647E-09	1.050E-09	1.748E-10
5000.	6.935E-07	1.089E-08	7.299E-09	3.865E-09	1.633E-09	5.470E-10	1.408E-10
10000.	8.695E-07	4.658E-09	3.121E-09	1.650E-09	6.953E-10	2.315E-10	5.832E-11
20000.	9.566E-07	-1.245E-10	-1.011E-10	-7.593E-11	-4.897E-11	-2.749E-11	-1.493E-11
Equal Temp.	3.838E-07	2.243E-07	8.071E-08	1.382E-08	-1.532E-08	-1.403E-08	-3.494E-09

See appendix for Chebychev fit details.

$O^{5+} + H \rightarrow O^{4+} + H^{+}$



Total Electron Capture Rate Coefficients for
$H + O^{5+} \rightarrow O^{4+} + H^+$

Beam - Maxwellian Rate Coefficients (cm^3/s)

O^{5+} Temp. (eV)	H Energy (eV/amu) 10000.	20000.	40000.	70000.	100000.	200000.	500000.
3.2E+00	4.28E-07	5.46E-07	5.95E-07	4.34E-07	2.31E-07	2.81E-08	7.62E-10
6.4E+00	4.28E-07	5.46E-07	5.94E-07	4.34E-07	2.34E-07	2.83E-08	7.65E-10
1.1E+01	4.28E-07	5.46E-07	5.94E-07	4.33E-07	2.33E-07	2.86E-08	7.65E-10
1.6E+01	4.28E-07	5.46E-07	5.94E-07	4.33E-07	2.33E-07	2.86E-08	7.65E-10
3.2E+01	4.28E-07	5.46E-07	5.94E-07	4.33E-07	2.33E-07	2.85E-08	7.65E-10
6.4E+01	4.28E-07	5.46E-07	5.94E-07	4.33E-07	2.33E-07	2.86E-08	7.65E-10
1.1E+02	4.28E-07	5.46E-07	5.93E-07	4.33E-07	2.33E-07	2.86E-08	7.65E-10
1.6E+02	4.28E-07	5.46E-07	5.93E-07	4.32E-07	2.33E-07	2.86E-08	7.65E-10
3.2E+02	4.28E-07	5.45E-07	5.92E-07	4.32E-07	2.33E-07	2.86E-08	7.65E-10
6.4E+02	4.28E-07	5.44E-07	5.91E-07	4.31E-07	2.33E-07	2.87E-08	7.66E-10
1.1E+03	4.29E-07	5.45E-07	5.90E-07	4.30E-07	2.33E-07	2.88E-08	7.67E-10
1.6E+03	4.28E-07	5.44E-07	5.89E-07	4.29E-07	2.34E-07	2.88E-08	7.68E-10
3.2E+03	4.30E-07	5.42E-07	5.86E-07	4.27E-07	2.34E-07	2.90E-08	7.71E-10
6.4E+03	4.32E-07	5.42E-07	5.81E-07	4.23E-07	2.34E-07	2.94E-08	7.77E-10
1.1E+04	4.35E-07	5.41E-07	5.75E-07	4.19E-07	2.35E-07	3.00E-08	7.87E-10
1.6E+04	4.38E-07	5.39E-07	5.70E-07	4.16E-07	2.36E-07	3.05E-08	7.96E-10
2.0E+04	4.39E-07	5.39E-07	5.66E-07	4.13E-07	2.36E-07	3.09E-08	8.04E-10

Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 3.2E+00 eV, E_{max} = 2.0E+04 eV

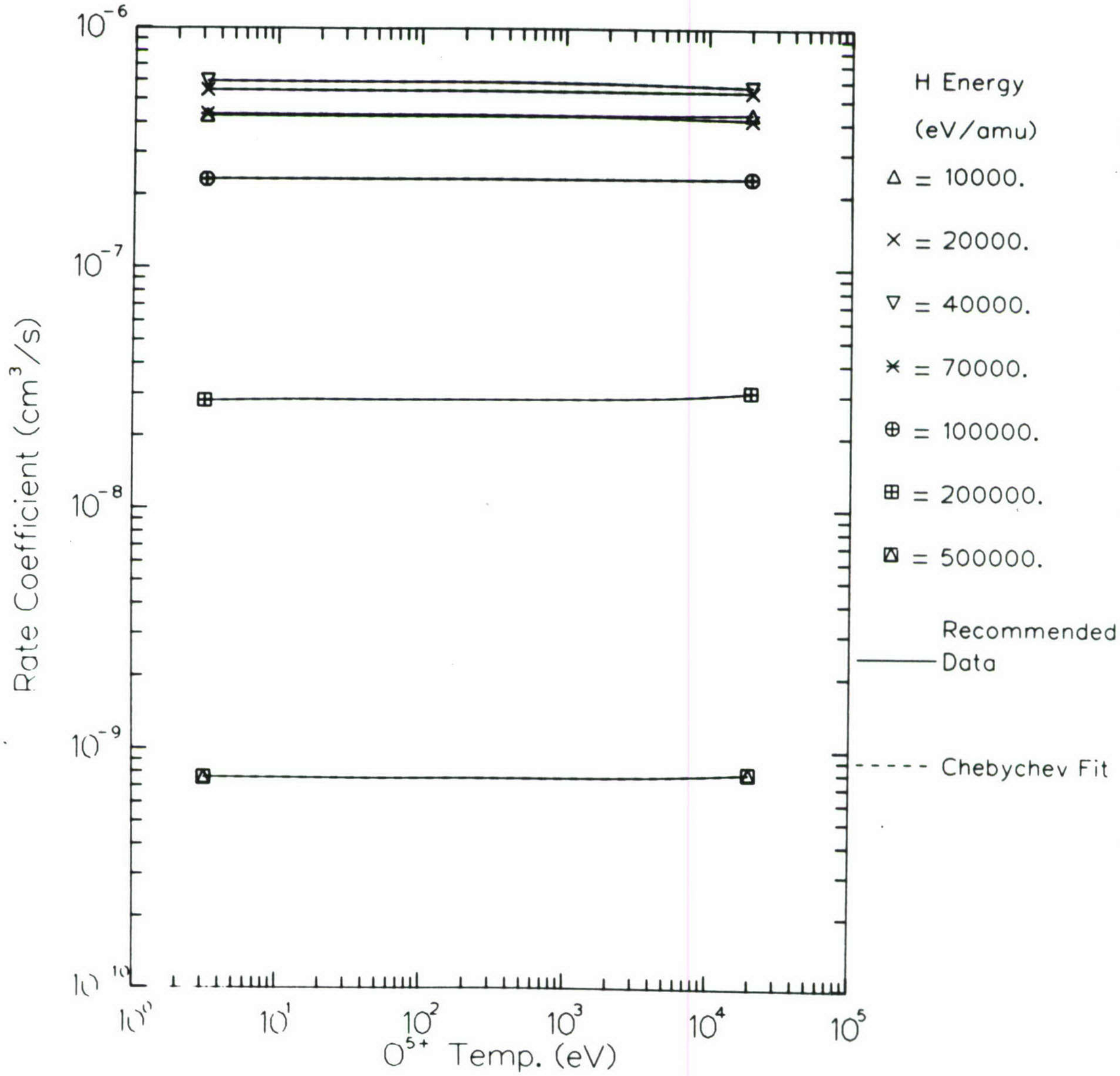
Chebychev Fitting Parameters for Rate Coefficients

H Energy (eV/amu)	C1	C2	C3	C4	C5	C6	C7
10000.	8.604E-07	4.080E-09	2.811E-09	1.557E-09	6.618E-10	1.776E-10	-6.401E-12
20000.	1.088E-06	-3.111E-09	-1.431E-09	-3.702E-10	-8.103E-11	-3.768E-13	-2.533E-11
40000.	1.175E-06	-1.144E-08	-5.989E-09	-2.735E-09	-7.484E-10	-3.238E-10	6.500E-11
70000.	8.565E-07	-8.536E-09	-4.302E-09	-1.903E-09	-5.365E-10	-1.881E-10	-9.626E-12
100000.	4.674E-07	1.310E-09	3.098E-10	5.780E-10	-2.172E-10	2.565E-10	-2.963E-10
200000.	5.797E-08	1.005E-09	4.361E-10	3.610E-10	6.255E-11	6.577E-11	2.306E-11
500000.	1.544E-09	1.409E-11	8.813E-12	5.574E-12	2.060E-12	1.151E-12	1.090E-13

See appendix for Chebychev fit details.

$H + O^{5+} \rightarrow O^{4+} + H^{+}$

Beam — Maxwellian



Total Electron Capture Cross Sections for
$O^{6+} + H \rightarrow O^{5+} + H^+$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
7.0E+01	1.16E+07	2.53E-15
1.0E+02	1.39E+07	2.90E-15
2.0E+02	1.96E+07	3.56E-15
4.0E+02	2.78E+07	3.72E-15
7.0E+02	3.68E+07	3.35E-15
1.0E+03	4.39E+07	3.31E-15
1.3E+03	4.91E+07	3.28E-15
2.0E+03	6.21E+07	3.23E-15
4.0E+03	8.79E+07	3.63E-15
7.0E+03	1.16E+08	3.87E-15
1.0E+04	1.39E+08	4.18E-15
2.0E+04	1.96E+08	4.02E-15
4.0E+04	2.78E+08	2.76E-15
7.0E+04	3.68E+08	1.44E-15
1.0E+05	4.39E+08	6.55E-16
2.0E+05	6.21E+08	8.21E-17
3.0E+05	7.61E+08	1.45E-17

References: E.7, E.8, E.9, E.17, E.19, T.1, T.8, T.9, T.16, T.17

Accuracy: 25% for $70 \lesssim E(eV/amu) \lesssim 3x10^4$; 30% for $E > 3x10^4$ eV/amu

Notes: (1) In the energy region $10^2 \lesssim E(eV/amu) \lesssim 10^5$, the n=4 shell of the O^{5+} product ion is dominantly populated [T.16]. For $E \lesssim 10^3$ eV/amu capture goes predominantly to the 4f level, while for $E \gtrsim 1.5x10^3$ eV/amu, the 4p level is most populated [E.19].

(2) In analogy with C^{4+} + H and C^{6+} + H electron capture reactions, one can expect that the tendency of the cross section to decrease with decreasing energy will continue down to ~ 2 eV/amu. Below 2 eV/amu the cross section is expected to rise again with decreasing energy due to population of the n = 5 shell of O^{5+}.

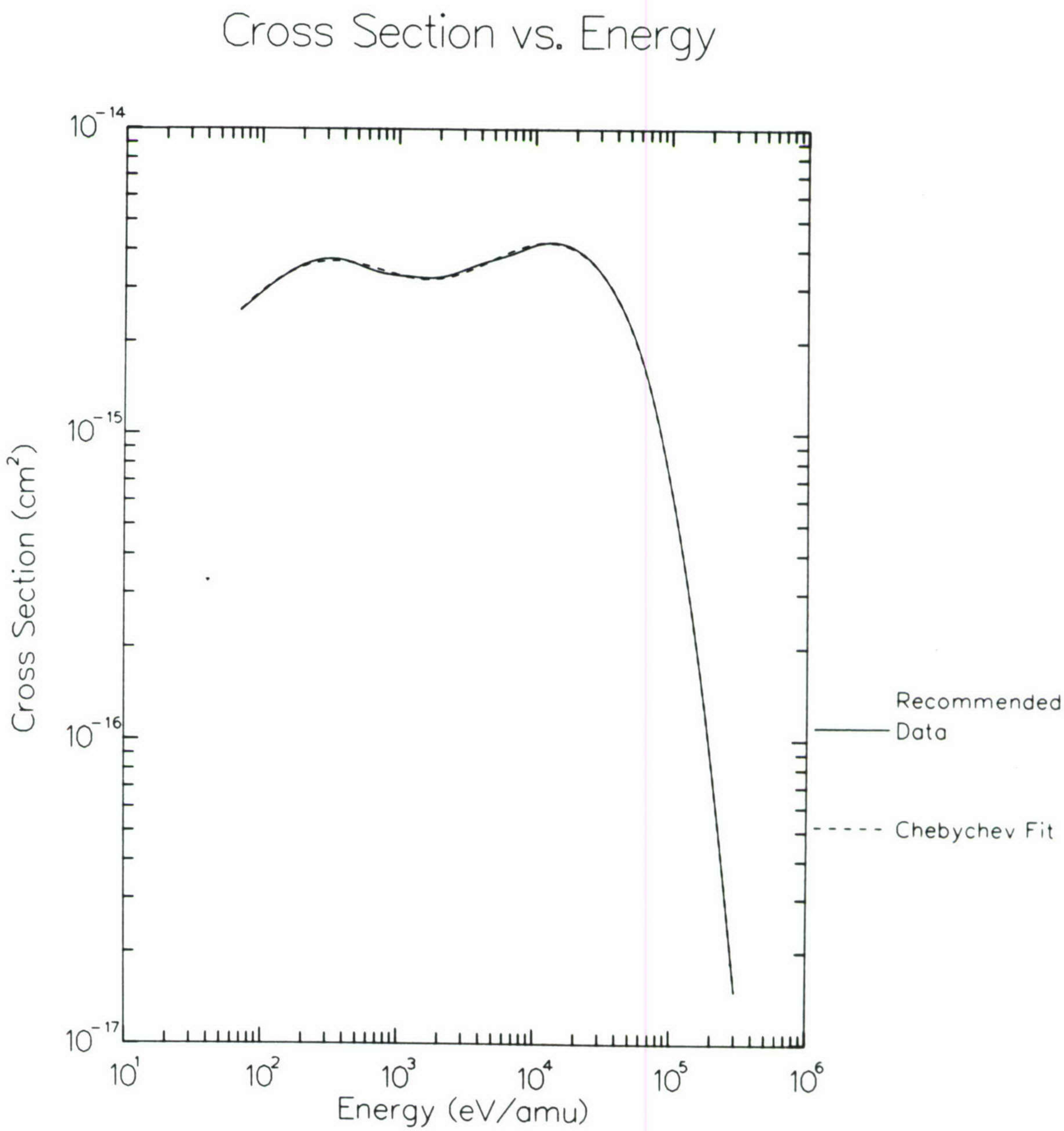
For Chebychev fits of the above cross sections it is necessary to use the following parameters.
E_{min} = 7.0E+01 eV/amu, E_{max} = 3.0E+05 eV/amu

Chebychev Fitting Parameters for Cross Sections

C1	C2	C3	C4	C5	C6	C7	C8	C9
4.895E-15	-1.393E-15	-1.342E-15	-2.151E-16	1.042E-16	5.471E-16	1.459E-16	-1.928E-16	-8.671E-17

The fit represents the above cross sections with an rms deviation of 1.5%.
The maximum deviation is 3.5% at 7.0E+02 eV/amu.
See appendix for Chebychev fit details.

$O^{6+} + H \rightarrow O^{5+} + H^{+}$



Total Electron Capture Rate Coefficients for
$O^{6+} + H \rightarrow O^{5+} + H^+$

Maxwellian - Maxwellian Rate Coefficients (cm^3/s)

O^{6+} Temp. (eV)	Equal Temp.	H Temp. (eV) 1.	10.	100.	1000.	5000.	10000.	20000.
6.4E+01	3.50E-08	5.14E-10	4.19E-09	4.95E-08	1.68E-07	4.28E-07	5.77E-07	6.39E-07
1.1E+02	5.45E-08	1.40E-09	5.93E-09	5.06E-08	1.68E-07	4.28E-07	5.77E-07	6.39E-07
1.6E+02	6.85E-08	2.65E-09	7.78E-09	5.16E-08	1.69E-07	4.28E-07	5.77E-07	6.39E-07
3.2E+02	9.86E-08	8.42E-09	1.42E-08	5.48E-08	1.69E-07	4.29E-07	5.77E-07	6.39E-07
6.4E+02	1.38E-07	2.09E-08	2.60E-08	6.08E-08	1.71E-07	4.30E-07	5.77E-07	6.39E-07
1.1E+03	1.84E-07	3.64E-08	4.03E-08	6.85E-08	1.74E-07	4.31E-07	5.78E-07	6.39E-07
1.6E+03	2.26E-07	4.84E-08	5.16E-08	7.51E-08	1.77E-07	4.32E-07	5.79E-07	6.39E-07
3.2E+03	3.44E-07	7.53E-08	7.72E-08	9.28E-08	1.85E-07	4.37E-07	5.80E-07	6.39E-07
6.4E+03	4.98E-07	1.07E-07	1.08E-07	1.19E-07	2.02E-07	4.46E-07	5.84E-07	6.39E-07
1.1E+04	6.05E-07	1.40E-07	1.41E-07	1.49E-07	2.26E-07	4.58E-07	5.88E-07	6.39E-07
1.6E+04	6.38E-07	1.68E-07	1.69E-07	1.77E-07	2.49E-07	4.70E-07	5.93E-07	6.38E-07
2.0E+04	6.38E-07	1.90E-07	1.90E-07	1.98E-07	2.68E-07	4.79E-07	5.96E-07	6.38E-07

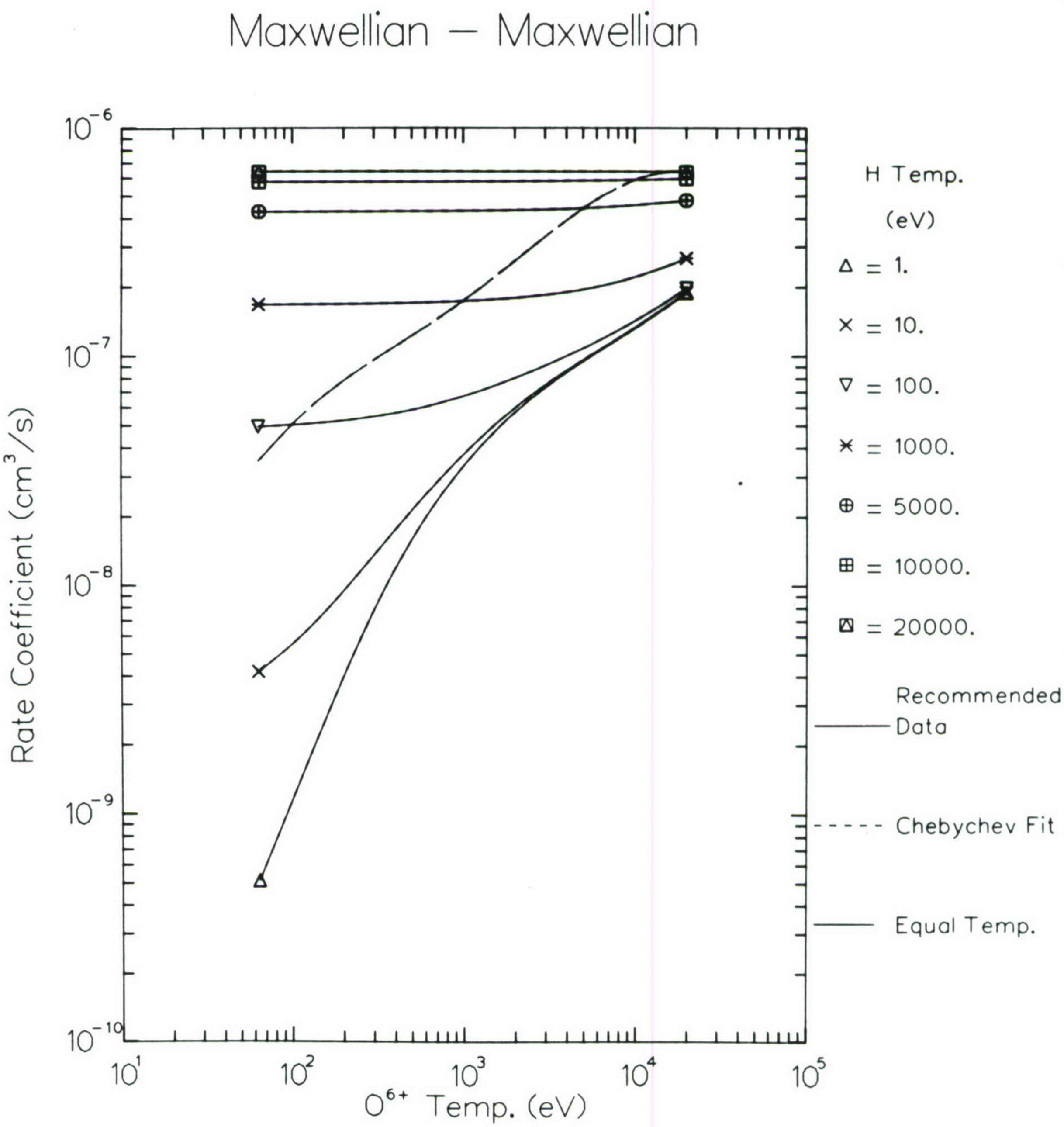
Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 6.4E+01 eV, E_{max} = 2.0E+04 eV

Chebychev Fitting Parameters for Rate Coefficients

H Temp. (eV)	C1	C2	C3	C4	C5	C6	C7
1.	1.286E-07	9.003E-08	2.877E-08	2.806E-09	1.658E-09	1.905E-09	5.149E-10
10.	1.347E-07	8.785E-08	2.788E-08	3.763E-09	1.635E-09	1.538E-09	4.798E-10
100.	1.886E-07	6.615E-08	2.726E-08	7.291E-09	1.904E-09	8.079E-10	2.924E-10
1000.	3.870E-07	4.087E-08	2.190E-08	8.481E-09	2.468E-09	5.201E-10	3.730E-11
5000.	8.818E-07	2.090E-08	1.121E-08	4.313E-09	1.189E-09	2.044E-10	1.517E-11
10000.	1.164E-06	8.044E-09	4.292E-09	1.644E-09	4.599E-10	8.539E-11	3.152E-12
20000.	1.278E-06	-5.588E-10	-3.445E-10	-1.731E-10	-7.425E-11	-2.913E-11	-1.132E-11
Equal Temp.	5.727E-07	3.246E-07	7.652E-08	-1.238E-08	-2.597E-08	-1.203E-08	-1.748E-09

See appendix for Chebychev fit details.

$O^{6+} + H \rightarrow O^{5+} + H^{+}$



Total Electron Capture Rate Coefficients for
$H + O^{6+} \rightarrow O^{5+} + H^+$

Beam - Maxwellian Rate Coefficients (cm^3/s)

O^{6+} Temp. (eV)	H Energy (eV/amu) 10000.	20000.	40000.	70000.	100000.	200000.	500000.
6.4E+01	5.80E-07	7.89E-07	7.66E-07	5.28E-07	2.88E-07	5.10E-08	1.38E-09
1.1E+02	5.80E-07	7.89E-07	7.66E-07	5.28E-07	2.88E-07	5.10E-08	1.38E-09
1.6E+02	5.80E-07	7.89E-07	7.66E-07	5.28E-07	2.88E-07	5.10E-08	1.38E-09
3.2E+02	5.79E-07	7.88E-07	7.65E-07	5.27E-07	2.88E-07	5.09E-08	1.38E-09
6.4E+02	5.79E-07	7.87E-07	7.65E-07	5.26E-07	2.88E-07	5.09E-08	1.38E-09
1.1E+03	5.79E-07	7.87E-07	7.63E-07	5.25E-07	2.89E-07	5.10E-08	1.38E-09
1.6E+03	5.79E-07	7.86E-07	7.63E-07	5.24E-07	2.89E-07	5.10E-08	1.39E-09
3.2E+03	5.81E-07	7.82E-07	7.60E-07	5.22E-07	2.89E-07	5.11E-08	1.39E-09
6.4E+03	5.85E-07	7.79E-07	7.55E-07	5.19E-07	2.90E-07	5.13E-08	1.40E-09
1.1E+04	5.90E-07	7.73E-07	7.49E-07	5.14E-07	2.92E-07	5.17E-08	1.41E-09
1.6E+04	5.96E-07	7.66E-07	7.42E-07	5.11E-07	2.93E-07	5.21E-08	1.43E-09
2.0E+04	5.99E-07	7.63E-07	7.39E-07	5.08E-07	2.93E-07	5.24E-08	1.44E-09

Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 6.4E+01 eV, E_{max} = 2.0E+04 eV

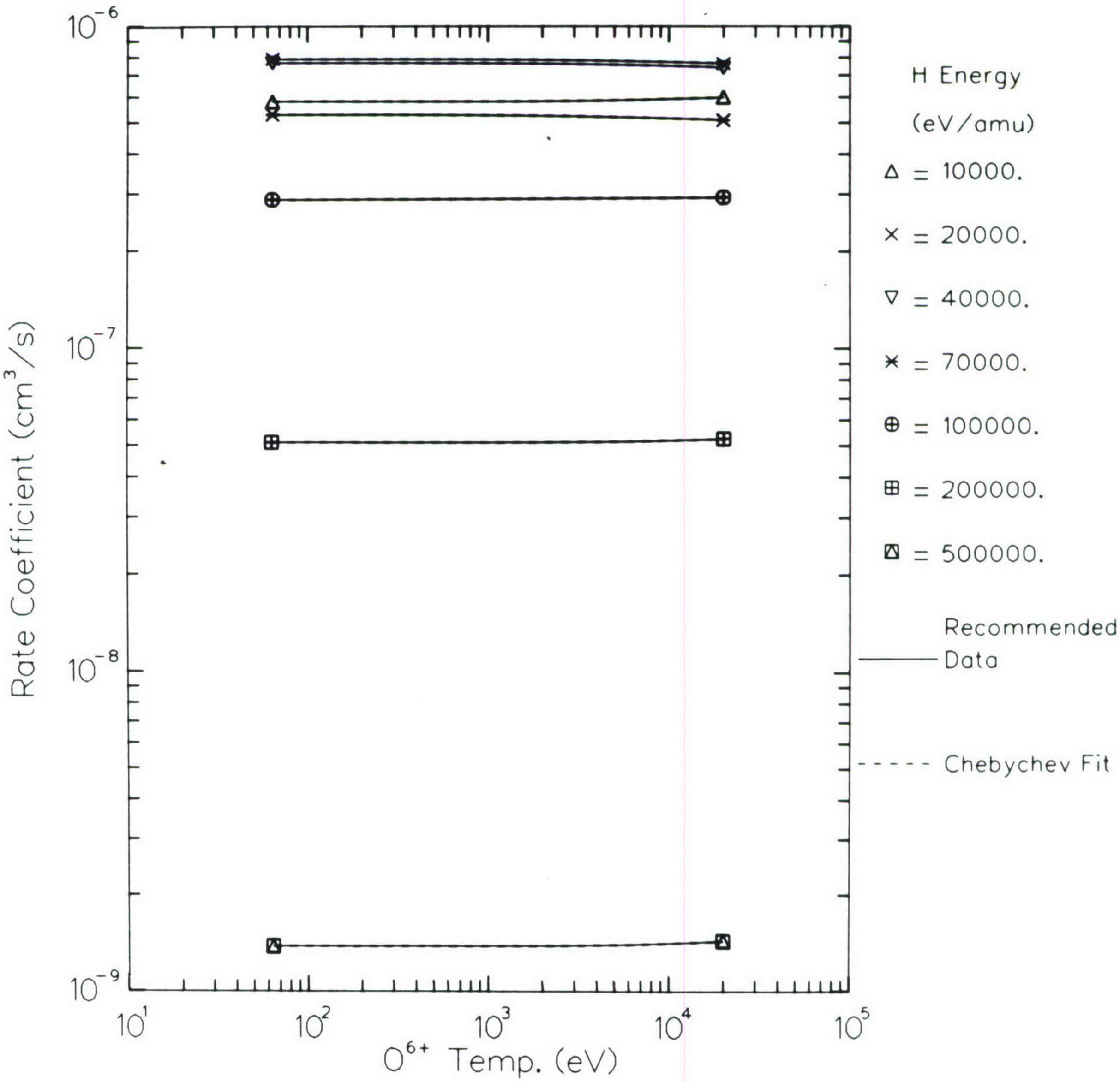
Chebychev Fitting Parameters for Rate Coefficients

H Energy (eV/amu)	C1	C2	C3	C4	C5	C6	C7
10000.	1.168E-06	7.458E-09	5.254E-09	2.021E-09	3.472E-10	-1.169E-10	-1.560E-10
20000.	1.563E-06	-1.156E-08	-5.324E-09	-1.809E-09	-4.969E-10	-9.495E-11	1.537E-12
40000.	1.517E-06	-1.187E-08	-5.655E-09	-1.977E-09	-4.927E-10	-6.243E-11	-1.102E-11
70000.	1.044E-06	-9.224E-09	-3.635E-09	-1.043E-09	-2.092E-10	5.820E-12	3.689E-11
100000.	5.790E-07	2.392E-09	9.976E-10	2.511E-10	-1.278E-11	-7.953E-11	-6.348E-11
200000.	1.025E-07	5.442E-10	3.689E-10	1.734E-10	6.253E-11	1.694E-11	1.240E-12
500000.	2.791E-09	2.273E-11	1.265E-11	5.362E-12	1.860E-12	5.910E-13	1.933E-13

See appendix for Chebychev fit details.

$H + O^{6+} \rightarrow O^{5+} + H^+$

Beam – Maxwellian



Total Electron Capture Cross Sections for
$O^{7+} + H \rightarrow O^{6+} + H^+$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
1.8E+02	1.85E+07	4.94E-15
2.0E+02	1.96E+07	4.97E-15
4.0E+02	2.78E+07	5.01E-15
7.0E+02	3.68E+07	5.08E-15
1.0E+03	4.39E+07	5.10E-15
1.3E+03	4.91E+07	5.07E-15
2.0E+03	6.21E+07	5.02E-15
4.0E+03	8.79E+07	5.00E-15
7.0E+03	1.16E+08	4.88E-15
1.0E+04	1.39E+08	4.75E-15
2.0E+04	1.96E+08	4.15E-15
4.0E+04	2.78E+08	3.68E-15
7.0E+04	3.68E+08	2.56E-15
1.0E+05	4.39E+08	1.44E-15
2.0E+05	6.21E+08	1.22E-16
4.0E+05	8.78E+08	7.10E-18

References: E.11, E.17, T.1, T.8, T.9

Accuracy: 20% for $1.5\times10^2 \leq E(\text{eV/amu}) \leq 2\times10^5$; 30% for $E > 2\times10^5$ eV/amu

Notes: (1) For $E \lesssim 10^4$ eV/amu, the cross sections for O^{7+} + H and N^{7+} + H have the same magnitude and energy behavior [E.11], which are close to theoretical predictions for N^{7+} + H [T.34], [T.22].

(2) Over a broad energy region (1×10^3 - 2.5×10^4 eV/amu) capture in this reaction is shared between the n=4 and n=5 shells of the product O^{6+} ion [T.34] providing a multitude of states and a quasi-resonant character.

(3) For $E \gtrsim 5\times10^4$ eV/amu capture goes dominantly to the n=4 shell of O^{6+} and for $E \lesssim 5\times10^2$ eV/amu the n=5 shell is most strongly populated [T.34], [T.22].

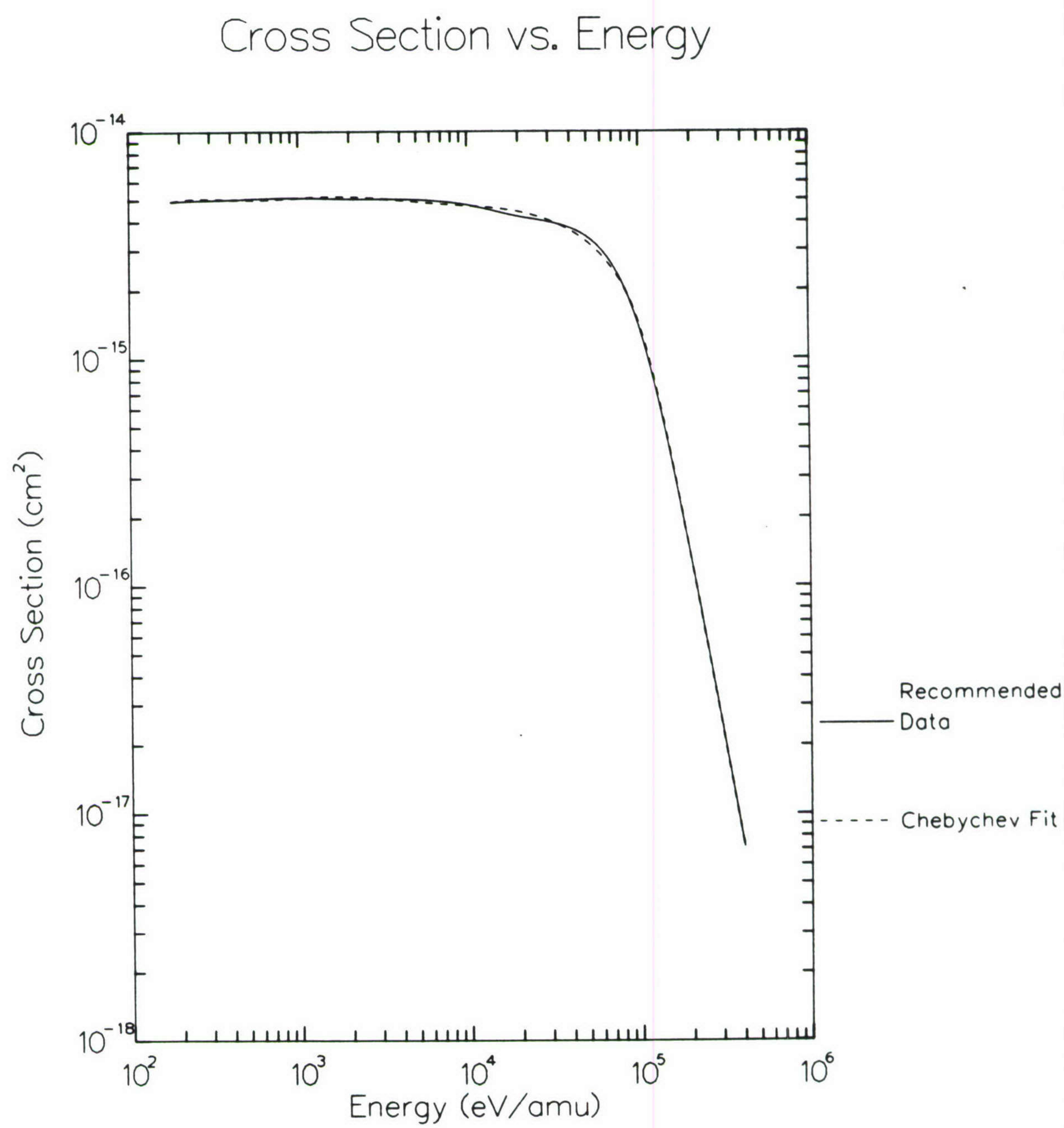
For Chebychev fits of the above cross sections it is necessary to use the following parameters.
E_{min} = 1.8E+02 eV/amu, E_{max} = 4.0E+05 eV/amu

Chebychev Fitting Parameters for Cross Sections

C1	C2	C3	C4	C5	C6	C7	C8	C9
6.744E-15	-2.663E-15	-1.241E-15	-5.988E-17	3.293E-16	2.921E-16	1.056E-16	-4.827E-18	-1.230E-16

The fit represents the above cross sections with an rms deviation of 2.6%.
The maximum deviation is 6.2% at 2.0E+04 eV/amu.
See appendix for Chebychev fit details.

$O^{7+} + H \rightarrow O^{6+} + H^{+}$



Total Electron Capture Rate Coefficients for
$O^{7+} + H \rightarrow O^{6+} + H^{+}$

Maxwellian - Maxwellian Rate Coefficients (cm^3/s)

O^{7+} Temp. (eV)	Equal Temp.	H Temp. (eV) 1.	10.	100.	1000.	5000.	10000.	20000.
6.4E+01	6.30E-08	1.24E-08*	2.60E-08	7.88E-08	2.50E-07	5.22E-07	6.74E-07	7.96E-07
1.1E+02	8.45E-08	1.80E-08	2.93E-08	7.99E-08	2.50E-07	5.22E-07	6.74E-07	7.96E-07
1.6E+02	1.02E-07	2.24E-08	3.22E-08	8.12E-08	2.50E-07	5.22E-07	6.74E-07	7.96E-07
3.2E+02	1.45E-07	3.31E-08	4.05E-08	8.49E-08	2.52E-07	5.23E-07	6.74E-07	7.96E-07
6.4E+02	2.06E-07	4.81E-08	5.35E-08	9.20E-08	2.54E-07	5.24E-07	6.74E-07	7.96E-07
1.1E+03	2.71E-07	6.45E-08	6.87E-08	1.02E-07	2.58E-07	5.25E-07	6.75E-07	7.96E-07
1.6E+03	3.22E-07	7.76E-08	8.12E-08	1.11E-07	2.61E-07	5.26E-07	6.76E-07	7.96E-07
2.8E+03	4.20E-07	1.04E-07	1.07E-07	1.31E-07	2.70E-07	5.29E-07	6.77E-07	7.97E-07
3.2E+03	4.44E-07	1.11E-07	1.14E-07	1.36E-07	2.72E-07	5.30E-07	6.78E-07	7.97E-07
6.4E+03	5.88E-07	1.58E-07	1.60E-07	1.77E-07	2.94E-07	5.38E-07	6.82E-07	7.98E-07
1.1E+04	7.10E-07	2.09E-07	2.10E-07	2.23E-07	3.22E-07	5.50E-07	6.88E-07	7.99E-07
1.6E+04	7.76E-07	2.49E-07	2.50E-07	2.61E-07	3.48E-07	5.61E-07	6.94E-07	8.00E-07
2.0E+04	8.01E-07	2.78E-07	2.79E-07	2.88E-07	3.68E-07	5.70E-07	6.99E-07	8.01E-07

Accuracy: * - Possible Error Greater Than 10%
** - Possible Error Greater Than 100%

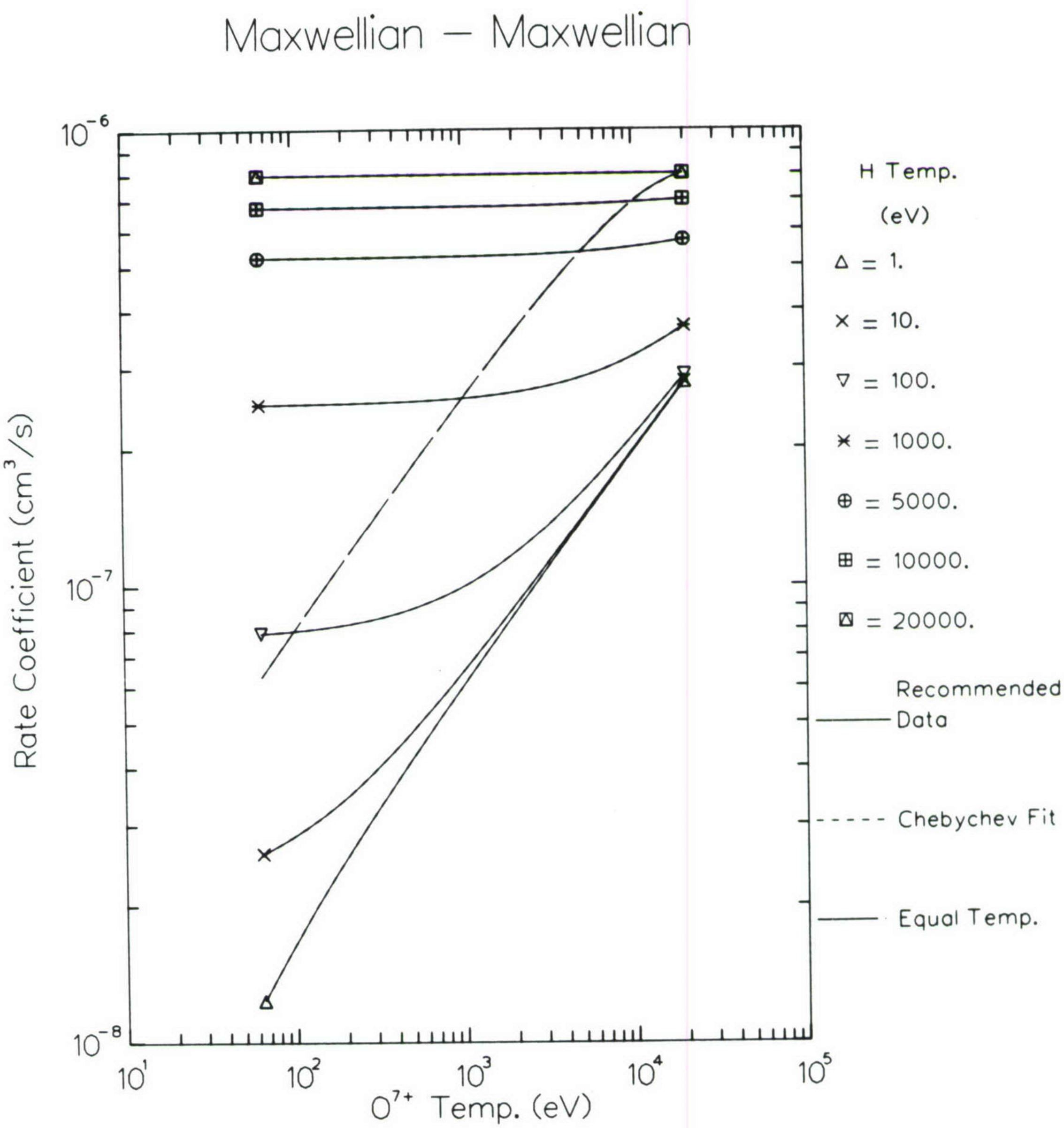
Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 6.4E+01 eV, E_{max} = 2.0E+04 eV

Chebychev Fitting Parameters for Rate Coefficients

H Temp. (eV)	C1	C2	C3	C4	C5	C6	C7
1.	2.075E-07	1.237E-07	4.018E-08	8.994E-09	1.260E-09	6.264E-11	-5.089E-12
10.	2.190E-07	1.175E-07	4.176E-08	8.849E-09	1.225E-09	9.692E-11	-6.065E-12
100.	2.831E-07	9.444E-08	4.079E-08	1.043E-08	1.265E-09	-2.469E-11	1.245E-11
1000.	5.621E-07	4.979E-08	2.563E-08	9.138E-09	2.214E-09	2.811E-10	-3.634E-11
5000.	1.068E-06	1.948E-08	1.049E-08	4.109E-09	1.208E-09	2.609E-10	3.446E-11
10000.	1.360E-06	1.005E-08	5.464E-09	2.213E-09	7.360E-10	2.102E-10	2.122E-11
20000.	1.595E-06	2.249E-09	1.196E-09	4.535E-10	1.236E-10	2.121E-11	-2.601E-13
Equal Temp.	7.292E-07	3.819E-07	8.106E-08	-7.425E-09	-1.187E-08	-4.730E-09	-1.021E-09

See appendix for Chebychev fit details.

$O^{7+} + H \rightarrow O^{6+} + H^{+}$



Total Electron Capture Rate Coefficients for
$H + O^{7+} \rightarrow O^{6+} + H^{+}$

Beam - Maxwellian Rate Coefficients (cm^3/s)

O^{7+} Temp. (eV)	H Energy (eV/amu) 10000.	20000.	40000.	70000.	100000.	200000.	500000.
6.4E+01	6.60E-07	8.16E-07	1.02E-06	9.39E-07	6.32E-07	7.60E-08	2.75E-09
1.1E+02	6.60E-07	8.16E-07	1.02E-06	9.39E-07	6.32E-07	7.61E-08	2.75E-09
1.6E+02	6.60E-07	8.16E-07	1.02E-06	9.38E-07	6.31E-07	7.61E-08	2.75E-09
3.2E+02	6.59E-07	8.17E-07	1.02E-06	9.37E-07	6.31E-07	7.63E-08	2.75E-09
6.4E+02	6.60E-07	8.17E-07	1.02E-06	9.35E-07	6.30E-07	7.66E-08	2.75E-09
1.1E+03	6.60E-07	8.18E-07	1.01E-06	9.33E-07	6.29E-07	7.69E-08	2.75E-09
1.6E+03	6.59E-07	8.19E-07	1.01E-06	9.31E-07	6.29E-07	7.72E-08	2.76E-09
2.8E+03	6.61E-07	8.19E-07	1.01E-06	9.28E-07	6.27E-07	7.78E-08	2.76E-09
3.2E+03	6.61E-07	8.19E-07	1.01E-06	9.27E-07	6.26E-07	7.80E-08	2.76E-09
6.4E+03	6.62E-07	8.22E-07	1.00E-06	9.19E-07	6.24E-07	7.93E-08	2.77E-09
1.1E+04	6.65E-07	8.26E-07	9.98E-07	9.08E-07	6.20E-07	8.13E-08	2.79E-09
1.6E+04	6.70E-07	8.27E-07	9.90E-07	9.01E-07	6.16E-07	8.30E-08	2.81E-09
2.0E+04	6.72E-07	8.32E-07	9.88E-07	8.94E-07	6.13E-07	8.44E-08	2.83E-09

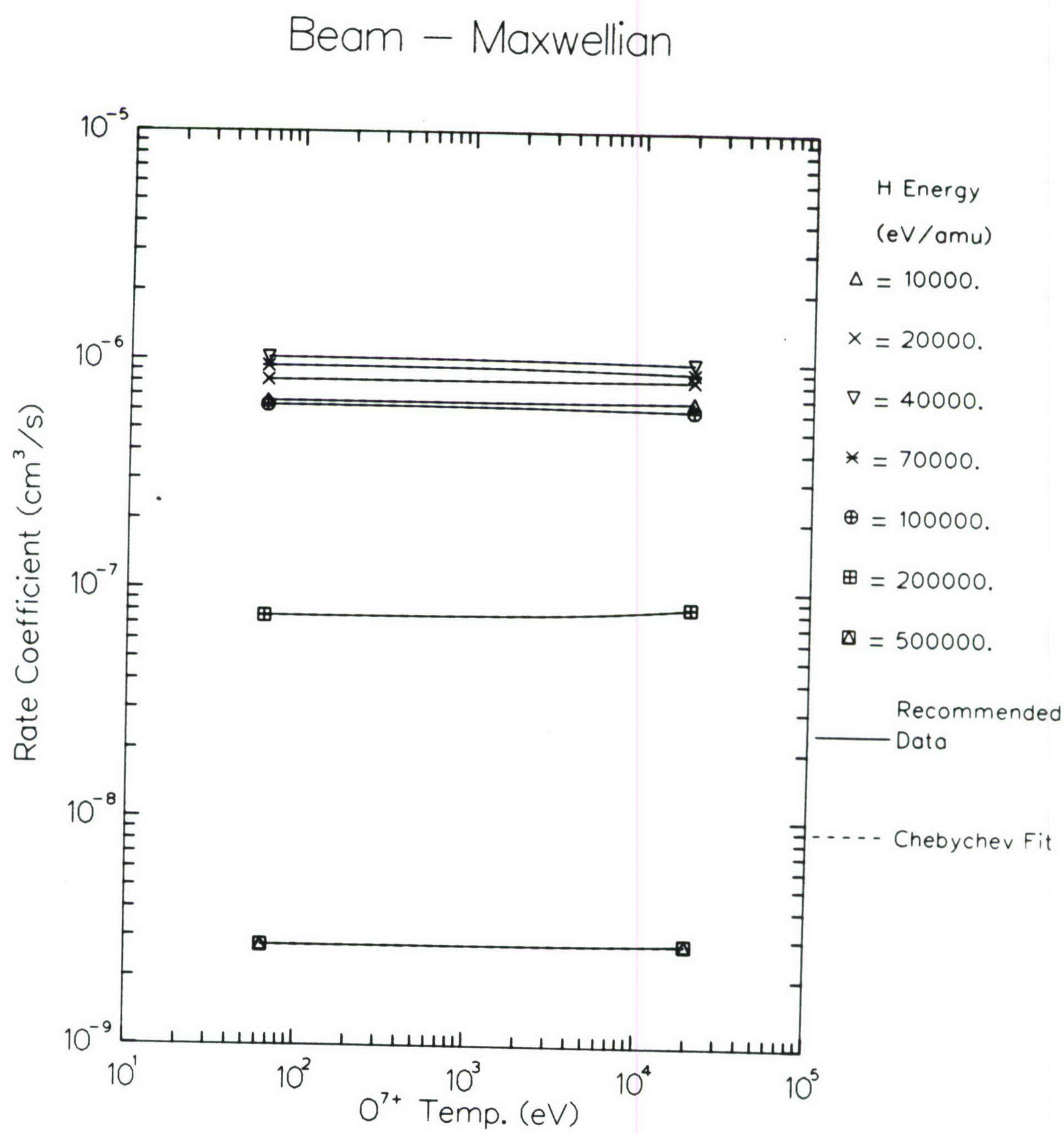
Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 6.4E+01 eV, E_{max} = 2.0E+04 eV

Chebychev Fitting Parameters for Rate Coefficients

H Energy (eV/amu)	C1	C2	C3	C4	C5	C6	C7
10000.	1.324E-06	4.570E-09	3.180E-09	1.361E-09	4.125E-10	9.166E-11	-5.709E-11
20000.	1.640E-06	6.436E-09	2.892E-09	1.076E-09	2.958E-10	5.610E-11	3.320E-11
40000.	2.020E-06	-1.534E-08	-5.634E-09	-1.396E-09	-1.288E-10	1.272E-10	5.894E-11
70000.	1.851E-06	-2.006E-08	-8.375E-09	-2.604E-09	-5.991E-10	-4.052E-11	5.881E-11
100000.	1.253E-06	-8.072E-09	-3.356E-09	-1.155E-09	-4.235E-10	-2.274E-10	-1.318E-10
200000.	1.567E-07	3.579E-09	1.656E-09	6.004E-10	1.839E-10	4.741E-11	6.879E-12
500000.	5.539E-09	3.226E-11	1.800E-11	7.706E-12	2.739E-12	9.234E-13	3.365E-13

See appendix for Chebychev fit details.

$H + O^{7+} \rightarrow O^{6+} + H^{+}$



Total Electron Capture Cross Sections for
$O^{8+} + H \rightarrow O^{7+} + H^+$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
1.5E+02	1.70E+07	1.38E-15
2.0E+02	1.96E+07	1.98E-15
4.0E+02	2.78E+07	3.30E-15
7.0E+02	3.68E+07	4.25E-15
1.0E+03	4.39E+07	4.76E-15
1.3E+03	4.91E+07	5.15E-15
2.0E+03	6.21E+07	5.48E-15
4.0E+03	8.79E+07	5.81E-15
7.0E+03	1.16E+08	5.83E-15
1.0E+04	1.39E+08	5.70E-15
2.0E+04	1.96E+08	5.20E-15
4.0E+04	2.78E+08	4.19E-15
7.0E+04	3.68E+08	2.97E-15
1.0E+05	4.39E+08	1.99E-15
2.0E+05	6.21E+08	1.46E-16
2.2E+05	6.51E+08	1.02E-16

References: E.9, E.11, E.19, T.8, T.9, T.22, T.23, T.34, T.35, T.36, T.37

Accuracy: 20% for $1.5 \times 10^2 \leq E(eV/amu) \leq 1.2 \times 10^5$; 30% for $E > 1.2 \times 10^5$ eV/amu

Notes: (1) Calculations [T.35] indicate that in the region 10 to 70 eV/amu the cross section should level-off to a value of ~ 10^{-15} cm^2 due to the increased role of capture into the n=6 shell.

(2) In the region between 10^2 and 2×10^4 eV/amu, capture dominantly goes to the n=5 shell of the O^{7+} product ion, [T.35], [T.22]. For higher energies, capture to the n=6 and n=7 shells also becomes significant [T.36], [T.23].

(3) In the region 10^2 to 2×10^4 eV/amu, the 5g sub-level is dominantly populated except for energies between 1×10^3 and 5×10^3 eV/amu, where population of the 5f level prevails.

For Chebychev fits of the above cross sections it is necessary to use the following parameters.
E_{min} = 1.5E+02 eV/amu, E_{max} = 2.2E+05 eV/amu

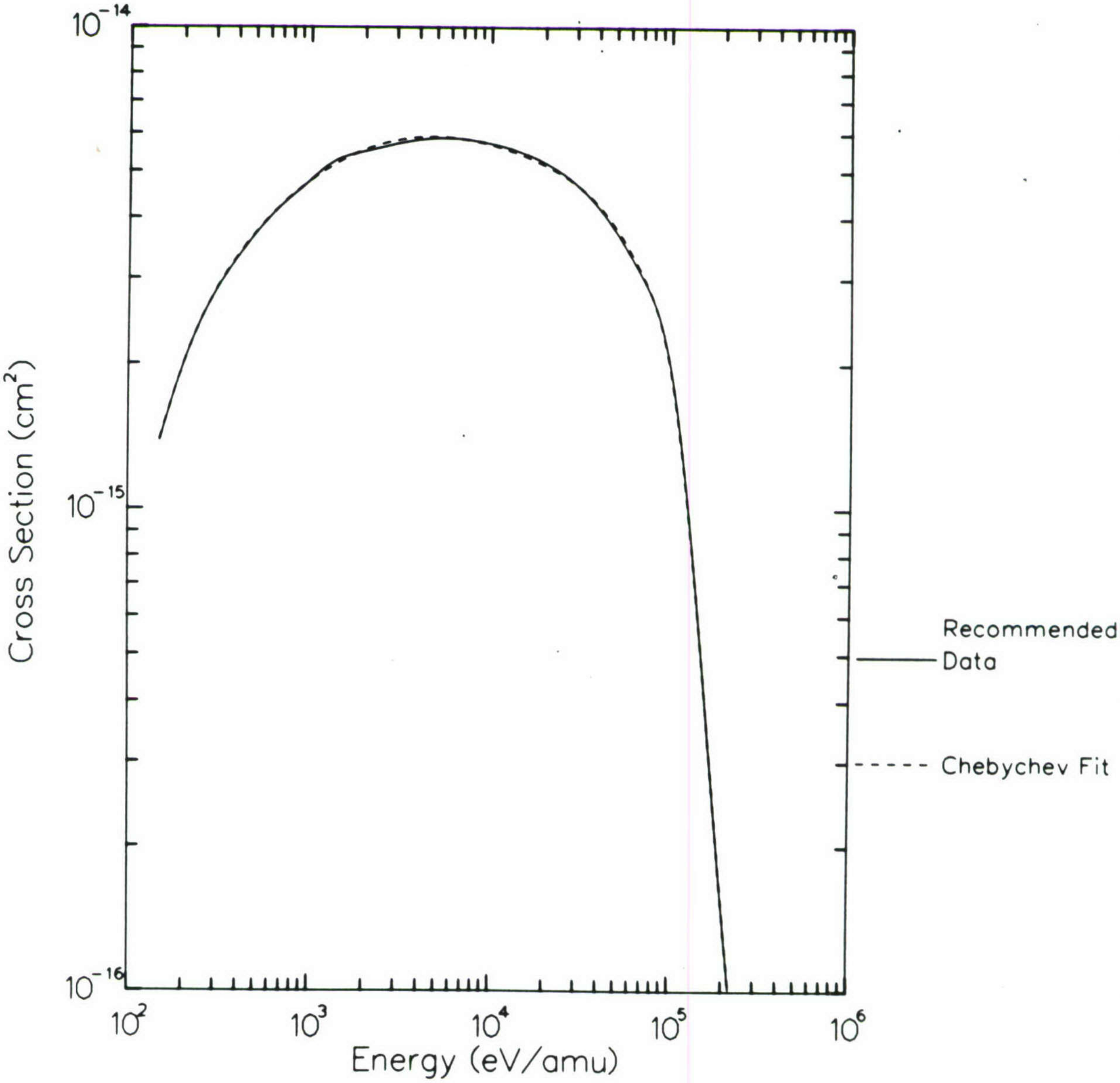
Chebychev Fitting Parameters for Cross Sections

C1	C2	C3	C4	C5	C6	C7	C8	C9
6.370E-15	-6.472E-16	-2.659E-15	-1.335E-16	8.584E-17	5.307E-17	9.227E-17	8.793E-17	3.766E-17

The fit represents the above cross sections with an rms deviation of 0.9%.
The maximum deviation is 1.4% at 7.0E+04 eV/amu.
See appendix for Chebychev fit details.

$O^{8+} + H \rightarrow O^{7+} + H^{+}$

Cross Section vs. Energy



Total Electron Capture Rate Coefficients for
$O^{8+} + H \rightarrow O^{7+} + H^{+}$

Maxwellian - Maxwellian Rate Coefficients (cm^3/s)

O^{8+} Temp. (eV)	Equal Temp.	H Temp. (eV) 1.	10.	100.	1000.	5000.	10000.	20000.
3.2E+01	9.07E-09	2.32E-09*	4.86E-09	3.00E-08	2.50E-07	6.16E-07	8.07E-07	9.50E-07
6.4E+01	1.85E-08	3.16E-09	5.24E-09	3.07E-08	2.51E-07	6.16E-07	8.07E-07	9.50E-07
1.1E+02	3.60E-08	4.00E-09	5.79E-09	3.18E-08	2.51E-07	6.16E-07	8.07E-07	9.50E-07
1.6E+02	5.38E-08	4.66E-09	6.33E-09	3.28E-08	2.52E-07	6.16E-07	8.07E-07	9.50E-07
3.2E+02	1.07E-07	6.51E-09	8.22E-09	3.63E-08	2.53E-07	6.17E-07	8.08E-07	9.50E-07
6.4E+02	1.90E-07	1.07E-08	1.31E-08	4.34E-08	2.57E-07	6.18E-07	8.08E-07	9.50E-07
1.1E+03	2.81E-07	1.94E-08	2.24E-08	5.38E-08	2.62E-07	6.19E-07	8.09E-07	9.50E-07
1.6E+03	3.50E-07	2.97E-08	3.28E-08	6.40E-08	2.67E-07	6.21E-07	8.10E-07	9.51E-07
2.4E+03	4.41E-07	4.72E-08	5.04E-08	8.02E-08	2.75E-07	6.24E-07	8.11E-07	9.51E-07
3.2E+03	5.12E-07	6.43E-08	6.73E-08	9.56E-08	2.82E-07	6.26E-07	8.12E-07	9.51E-07
6.4E+03	7.01E-07	1.24E-07	1.27E-07	1.50E-07	3.11E-07	6.37E-07	8.17E-07	9.52E-07
1.1E+04	8.51E-07	1.94E-07	1.96E-07	2.14E-07	3.50E-07	6.52E-07	8.25E-07	9.54E-07
1.6E+04	9.26E-07	2.50E-07	2.52E-07	2.67E-07	3.85E-07	6.66E-07	8.31E-07	9.55E-07
2.0E+04	9.56E-07	2.90E-07	2.91E-07	3.04E-07	4.12E-07	6.78E-07	8.37E-07	9.56E-07

Accuracy: * - Possible Error Greater Than 10%
** - Possible Error Greater Than 100%

Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 3.2E+01 eV, E_{max} = 2.0E+04 eV

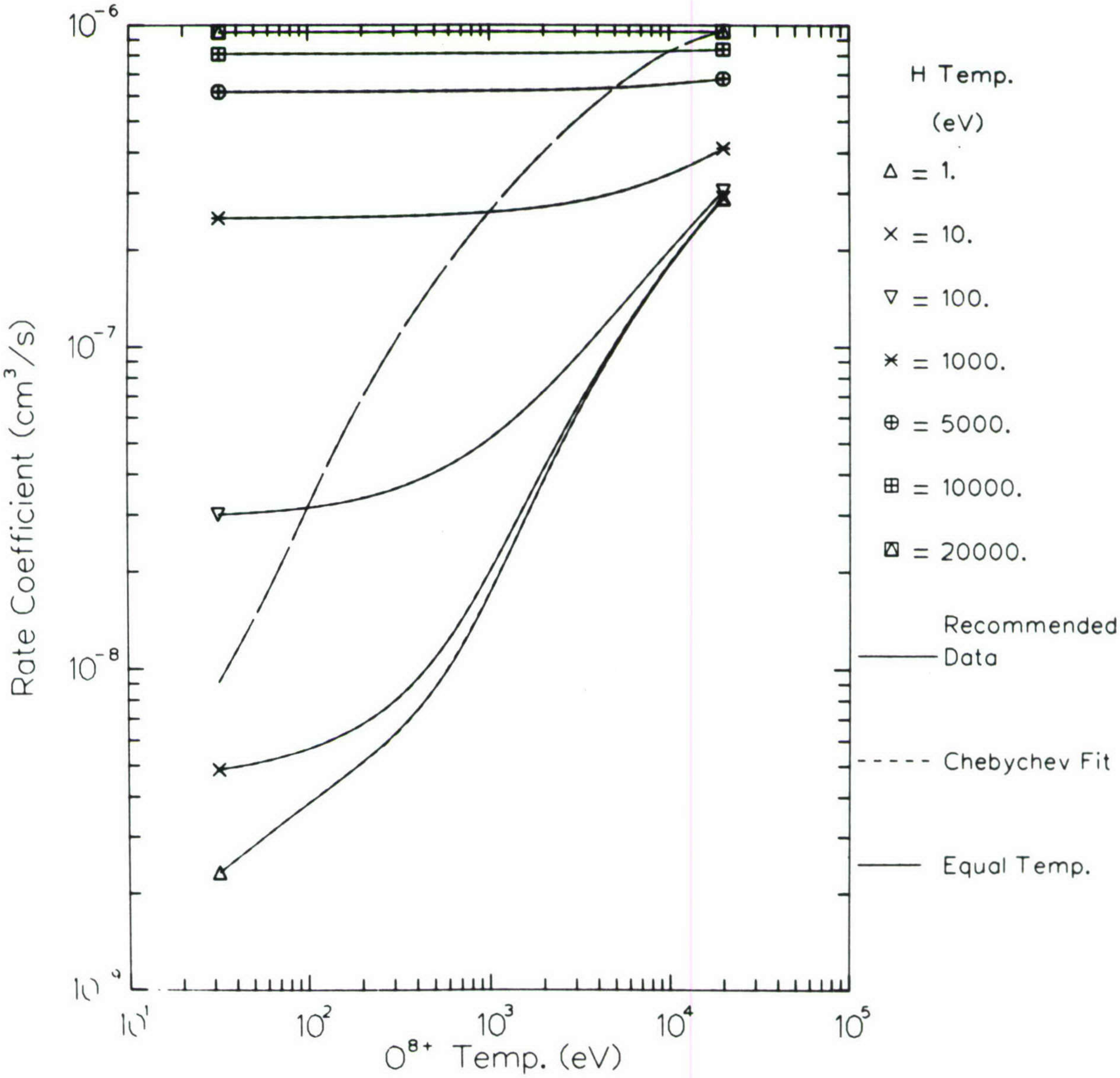
Chebychev Fitting Parameters for Rate Coefficients

H Temp. (eV)	C1	C2	C3	C4	C5	C6	C7
1.	1.548E-07	1.223E-07	6.647E-08	2.229E-08	1.787E-09	-1.986E-09	-7.370E-10
10.	1.591E-07	1.221E-07	6.623E-08	2.188E-08	2.184E-09	-1.453E-09	-5.426E-10
100.	2.075E-07	1.176E-07	6.049E-08	1.993E-08	3.293E-09	-3.787E-10	-3.265E-10
1000.	5.819E-07	6.588E-08	3.638E-08	1.421E-08	3.850E-09	6.000E-10	-3.799E-11
5000.	1.261E-06	2.453E-08	1.412E-08	6.029E-09	1.958E-09	4.751E-10	7.424E-11
10000.	1.629E-06	1.174E-08	6.743E-09	2.859E-09	9.076E-10	2.076E-10	3.881E-11
20000.	1.903E-06	2.574E-09	1.471E-09	6.173E-10	1.930E-10	4.238E-11	3.499E-12
Equal Temp.	7.434E-07	4.956E-07	1.321E-07	-1.461E-08	-1.841E-08	-6.435E-09	-1.742E-09

See appendix for Chebychev fit details.

$O^{8+} + H -> O^{7+} + H^{+}$

Maxwellian — Maxwellian



Total Electron Capture Rate Coefficients for
$H + O^{8+} \rightarrow O^{7+} + H^+$

Beam - Maxwellian Rate Coefficients (cm^3/s)

O^{8+} Temp. (eV)	H Energy (eV/amu) 10000.	20000.	40000.	70000.	100000.	200000.	500000.
3.2E+01	7.92E-07	1.02E-06	1.16E-06	1.09E-06	8.73E-07	9.10E-08	5.67E-09
6.4E+01	7.92E-07	1.02E-06	1.16E-06	1.09E-06	8.72E-07	9.11E-08	5.67E-09
1.1E+02	7.92E-07	1.02E-06	1.16E-06	1.09E-06	8.71E-07	9.13E-08	5.67E-09
1.6E+02	7.92E-07	1.02E-06	1.16E-06	1.09E-06	8.70E-07	9.14E-08	5.67E-09
3.2E+02	7.91E-07	1.02E-06	1.16E-06	1.09E-06	8.69E-07	9.17E-08	5.67E-09
6.4E+02	7.93E-07	1.02E-06	1.16E-06	1.09E-06	8.66E-07	9.22E-08	5.67E-09
1.1E+03	7.93E-07	1.02E-06	1.16E-06	1.09E-06	8.64E-07	9.28E-08	5.67E-09
1.6E+03	7.92E-07	1.02E-06	1.16E-06	1.09E-06	8.61E-07	9.33E-08	5.68E-09
2.4E+03	7.95E-07	1.02E-06	1.16E-06	1.08E-06	8.58E-07	9.41E-08	5.68E-09
3.2E+03	7.95E-07	1.02E-06	1.16E-06	1.08E-06	8.55E-07	9.47E-08	5.69E-09
6.4E+03	7.99E-07	1.02E-06	1.15E-06	1.08E-06	8.46E-07	9.71E-08	5.70E-09
1.1E+04	8.04E-07	1.02E-06	1.15E-06	1.07E-06	8.35E-07	1.00E-07	5.73E-09
1.6E+04	8.11E-07	1.02E-06	1.14E-06	1.07E-06	8.25E-07	1.03E-07	5.75E-09
2.0E+04	8.14E-07	1.02E-06	1.14E-06	1.06E-06	8.17E-07	1.06E-07	5.78E-09

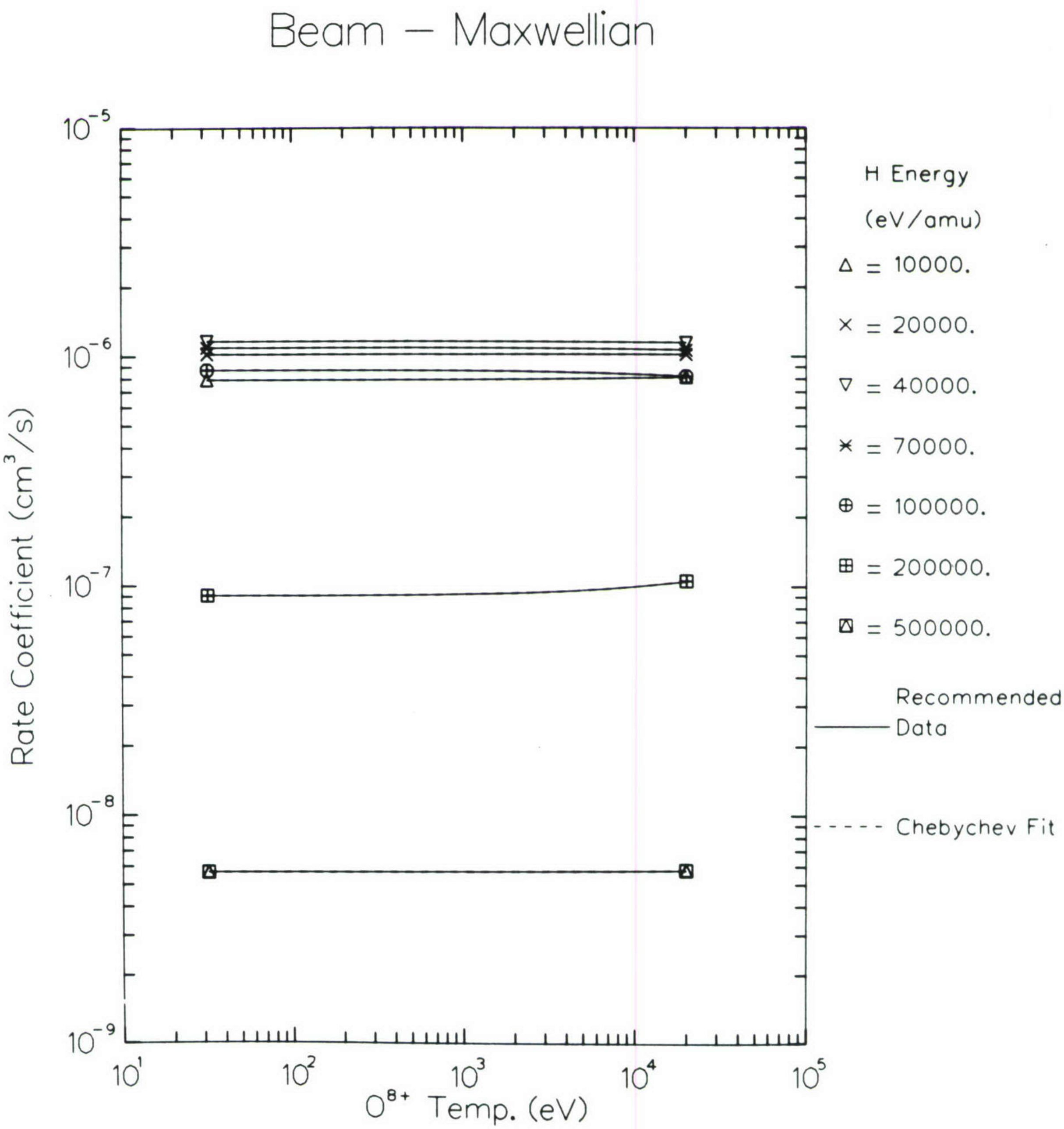
Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 3.2E+01 eV, E_{max} = 2.0E+04 eV

Chebychev Fitting Parameters for Rate Coefficients

H Energy (eV/amu)	C1	C2	C3	C4	C5	C6	C7
10000.	1.594E-06	8.644E-09	5.361E-09	2.335E-09	6.839E-10	1.483E-10	-7.725E-11
20000.	2.039E-06	-2.447E-09	-5.515E-10	1.073E-10	1.065E-10	6.960E-11	6.189E-11
40000.	2.315E-06	-9.174E-09	-4.370E-09	-1.457E-09	-2.537E-10	9.902E-11	1.065E-10
70000.	2.165E-06	-1.275E-08	-5.997E-09	-2.119E-09	-6.252E-10	-1.887E-10	-8.597E-12
100000.	1.712E-06	-2.406E-08	-1.015E-08	-3.267E-09	-9.202E-10	-3.169E-10	-1.875E-10
200000.	1.900E-07	6.124E-09	2.924E-09	1.115E-09	3.566E-10	1.035E-10	2.026E-11
500000.	1.139E-08	4.112E-11	2.440E-11	1.136E-11	4.464E-12	1.675E-12	7.443E-13

See appendix for Chebychev fit details.

$H + O^{8+} \rightarrow O^{7+} + H^{+}$



Total Electron Capture Cross Sections for
$C^+ + He \rightarrow C^+ + He^+$

No experimental or theoretical data were available for this reaction at the time of compilation.

Pages numbered 1-96 through 1-101 have been reserved for a possible future supplement, should data become available.

Total Electron Capture Cross Sections for
$C^{2+} + He \rightarrow C^{+} + He^{+}$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
1.0E+00	1.39E+06	2.58E-17
2.0E+00	1.96E+06	5.88E-17
4.0E+00	2.78E+06	1.16E-16
7.0E+00	3.68E+06	1.81E-16
1.0E+01	4.39E+06	2.40E-16
2.0E+01	6.21E+06	3.45E-16
4.0E+01	8.79E+06	4.60E-16
7.0E+01	1.16E+07	5.25E-16
1.0E+02	1.39E+07	5.55E-16
2.0E+02	1.96E+07	5.95E-16
4.0E+02	2.78E+07	6.05E-16
7.0E+02	3.68E+07	5.92E-16
1.0E+03	4.39E+07	5.73E-16
1.7E+03	5.67E+07	5.39E-16
2.0E+03	6.21E+07	5.24E-16
4.0E+03	8.79E+07	4.58E-16
7.0E+03	1.16E+08	3.86E-16
1.0E+04	1.39E+08	3.34E-16
2.0E+04	1.96E+08	2.51E-16
4.0E+04	2.78E+08	1.51E-16
7.0E+04	3.68E+08	8.54E-17
1.0E+05	4.39E+08	4.95E-17
1.2E+05	4.81E+08	3.73E-17

References: E.21, E.22, E.23, T.4, T.9

Accuracy: 40% for $1 \leq E(eV/amu) < 2 \times 10^2$; 60% for $2 \times 10^2 \leq E(eV/amu) < 1 \times 10^5$

Notes: (1) C^{2+} ion beams produced in plasma sources always contain a considerable fraction of metastable $C^{2+}(2s2p)\,^3P^0$ ions which give a predominant contribution to the total charge exchange cross section at energies below ~ 10^4 eV/amu [E.24].
(2) Calculations [T.4], made for $C^{2+}(2s2p)\,^3P^0$ + He collisions, show that the cross section continues to decrease in the region below 1 eV/amu, reaching a value of $\sigma = .9 \times 10^{-18}$ cm^2 at E = 0.1 eV/amu.

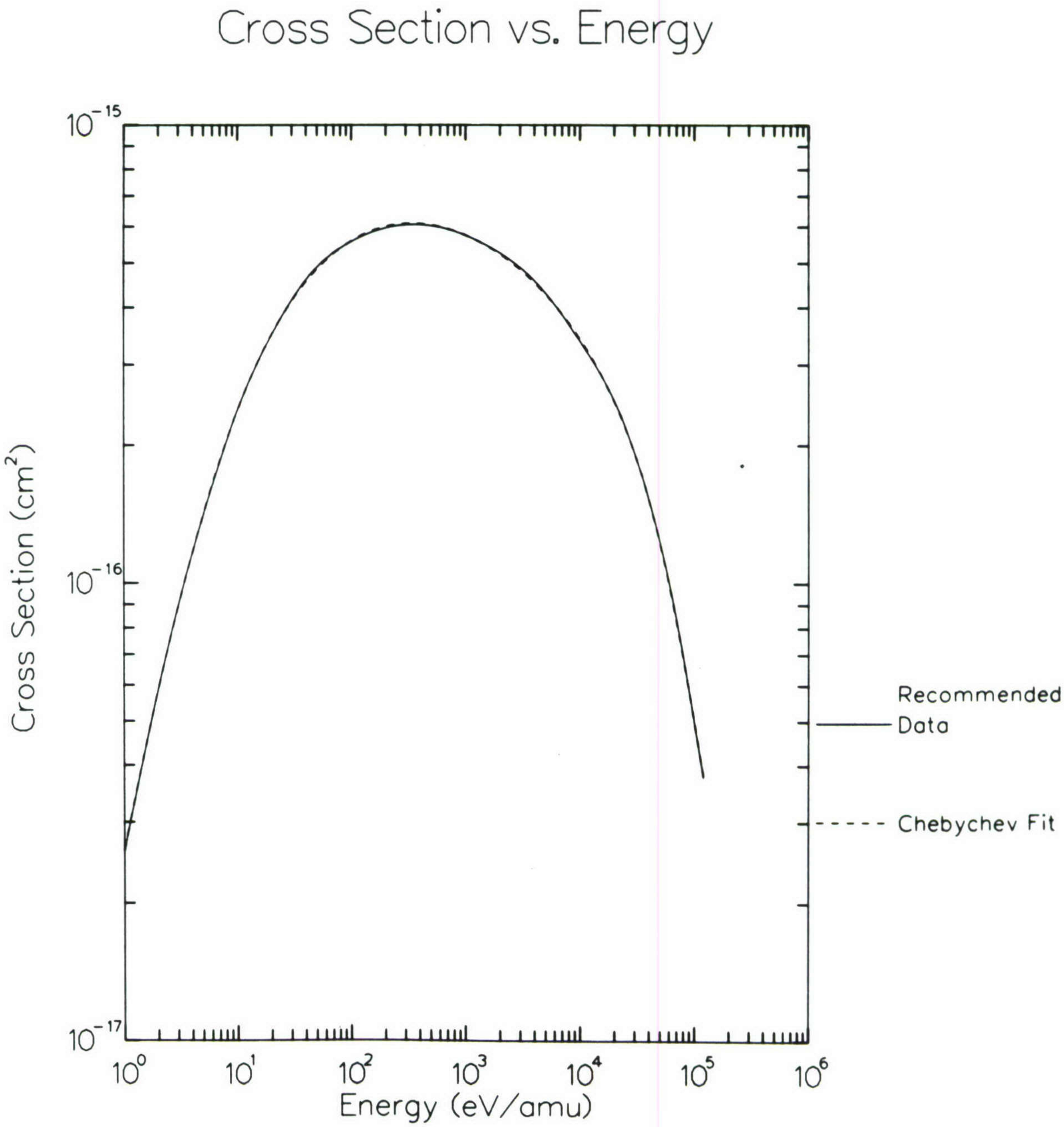
For Chebychev fits of the above cross sections it is necessary to use the following parameters.
E_{min} = 1.0E+00 eV/amu, E_{max} = 1.2E+05 eV/amu

Chebychev Fitting Parameters for Cross Sections

C1	C2	C3	C4	C5	C6	C7	C8	C9
5.166E-16	2.581E-17	-2.850E-16	-1.815E-17	6.263E-17	-8.500E-18	-3.529E-18	6.516E-18	-8.793E-19

The fit represents the above cross sections with an rms deviation of 1.0%.
The maximum deviation is 2.1% at 1.0E+04 eV/amu.
See appendix for Chebychev fit details.

$C^{2+} + He \rightarrow C^{+} + He^{+}$



Total Electron Capture Rate Coefficients for
$C^{2+} + He \rightarrow C^{+} + He^{+}$

Maxwellian - Maxwellian Rate Coefficients (cm^3/s)

C^{2+} Temp. (eV)	Equal Temp.	He Temp. (eV) 1.	10.	100.	1000.	5000.	10000.	20000.
1.2E+00	1.99E-11	1.57E-11	3.36E-10	3.45E-09	1.45E-08	2.85E-08	3.52E-08	4.07E-08
2.4E+00	6.27E-11	2.43E-11	3.53E-10	3.46E-09	1.45E-08	2.85E-08	3.52E-08	4.07E-08
4.8E+00	1.75E-10	4.50E-11	3.87E-10	3.48E-09	1.45E-08	2.85E-08	3.52E-08	4.07E-08
8.4E+00	3.70E-10	8.17E-11	4.38E-10	3.51E-09	1.45E-08	2.85E-08	3.52E-08	4.07E-08
1.2E+01	5.74E-10	1.23E-10	4.88E-10	3.54E-09	1.45E-08	2.85E-08	3.52E-08	4.07E-08
2.4E+01	1.23E-09	2.78E-10	6.58E-10	3.65E-09	1.46E-08	2.85E-08	3.52E-08	4.07E-08
4.8E+01	2.37E-09	6.16E-10	9.90E-10	3.86E-09	1.46E-08	2.85E-08	3.52E-08	4.07E-08
8.4E+01	3.75E-09	1.11E-09	1.46E-09	4.15E-09	1.47E-08	2.86E-08	3.52E-08	4.07E-08
1.2E+02	4.88E-09	1.57E-09	1.90E-09	4.44E-09	1.48E-08	2.86E-08	3.52E-08	4.07E-08
2.4E+02	7.72E-09	2.90E-09	3.16E-09	5.30E-09	1.51E-08	2.87E-08	3.52E-08	4.08E-08
4.8E+02	1.15E-08	4.90E-09	5.10E-09	6.78E-09	1.56E-08	2.88E-08	3.53E-08	4.08E-08
8.4E+02	1.53E-08	7.12E-09	7.26E-09	8.57E-09	1.64E-08	2.90E-08	3.54E-08	4.08E-08
1.2E+03	1.81E-08	8.85E-09	8.96E-09	1.01E-08	1.71E-08	2.93E-08	3.55E-08	4.09E-08
2.4E+03	2.42E-08	1.30E-08	1.31E-08	1.38E-08	1.91E-08	3.00E-08	3.58E-08	4.10E-08
4.8E+03	3.09E-08	1.81E-08	1.82E-08	1.86E-08	2.23E-08	3.12E-08	3.65E-08	4.12E-08
8.4E+03	3.62E-08	2.30E-08	2.30E-08	2.33E-08	2.59E-08	3.28E-08	3.73E-08	4.16E-08
1.2E+04	3.91E-08	2.64E-08	2.64E-08	2.66E-08	2.85E-08	3.42E-08	3.81E-08	4.19E-08
2.0E+04	4.24E-08	3.13E-08	3.13E-08	3.15E-08	3.27E-08	3.65E-08	3.94E-08	4.24E-08

Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.2E+00 eV, E_{max} = 2.0E+04 eV

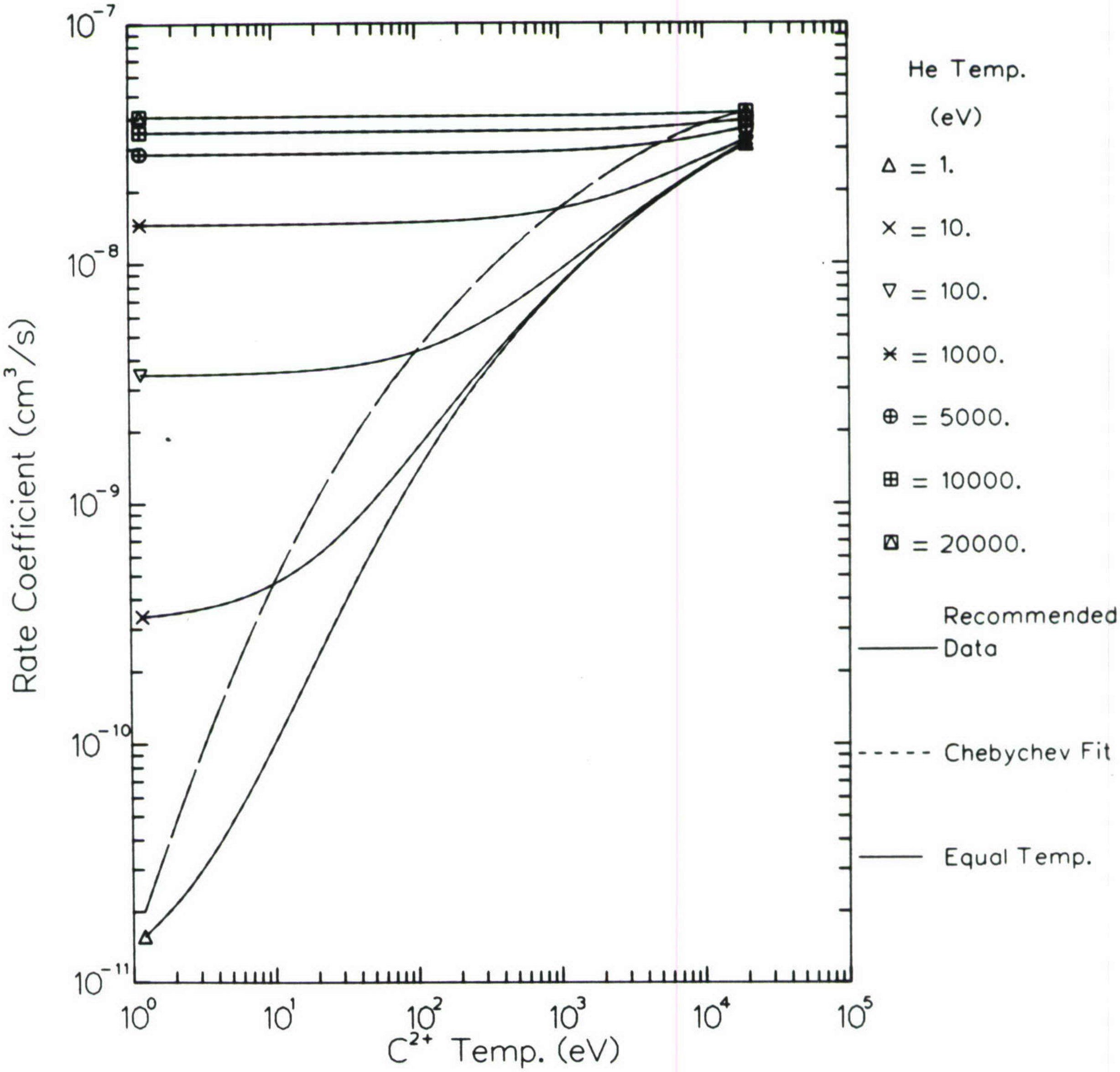
Chebychev Fitting Parameters for Rate Coefficients

He Temp. (eV)	C1	C2	C3	C4	C5	C6	C7
1.	1.794E-08	1.423E-08	6.851E-09	1.564E-09	-1.739E-10	-1.987E-10	-3.652E-11
10.	1.837E-08	1.405E-08	6.802E-09	1.629E-09	-1.287E-10	-1.986E-10	-4.076E-11
100.	2.214E-08	1.237E-08	6.456E-09	1.870E-09	6.965E-12	-2.292E-10	-7.749E-11
1000.	3.768E-08	7.327E-09	4.464E-09	1.849E-09	4.059E-10	-6.167E-11	-9.056E-11
5000.	6.047E-08	2.980E-09	1.968E-09	9.742E-10	3.431E-10	6.550E-11	-1.453E-11
10000.	7.207E-08	1.545E-09	1.043E-09	5.406E-10	2.102E-10	5.401E-11	8.592E-13
20000.	8.216E-08	6.114E-10	4.176E-10	2.226E-10	9.156E-11	2.707E-11	3.425E-12
Equal Temp.	2.906E-08	2.148E-08	7.816E-09	1.945E-10	-9.367E-10	-3.265E-10	-3.922E-11

See appendix for Chebychev fit details.

$C^{2+} + He \rightarrow C^{+} + He^{+}$

Maxwellian — Maxwellian



Total Electron Capture Rate Coefficients for
$He + C^{2+} \rightarrow C^{+} + He^{+}$

Beam - Maxwellian Rate Coefficients (cm^3/s)

C^{2+} Temp. (eV)	He Energy (eV/amu) 10000.	20000.	40000.	70000.	100000.	200000.	500000.
1.2E+00	4.64E-08	4.93E-08	4.20E-08	3.14E-08	2.17E-08	5.83E-09	4.92E-11*
2.4E+00	4.64E-08	4.93E-08	4.20E-08	3.14E-08	2.17E-08	5.83E-09	4.93E-11*
4.8E+00	4.64E-08	4.93E-08	4.20E-08	3.14E-08	2.17E-08	5.83E-09	4.93E-11*
8.4E+00	4.64E-08	4.93E-08	4.20E-08	3.14E-08	2.17E-08	5.83E-09	4.94E-11*
1.2E+01	4.64E-08	4.93E-08	4.20E-08	3.14E-08	2.17E-08	5.83E-09	4.95E-11*
2.4E+01	4.64E-08	4.93E-08	4.19E-08	3.14E-08	2.18E-08	5.83E-09	4.96E-11*
4.8E+01	4.64E-08	4.92E-08	4.19E-08	3.14E-08	2.18E-08	5.83E-09	4.98E-11*
8.4E+01	4.64E-08	4.92E-08	4.19E-08	3.14E-08	2.18E-08	5.83E-09	5.01E-11*
1.2E+02	4.64E-08	4.92E-08	4.19E-08	3.13E-08	2.18E-08	5.83E-09	5.03E-11*
2.4E+02	4.64E-08	4.92E-08	4.19E-08	3.13E-08	2.18E-08	5.83E-09	5.08E-11*
4.8E+02	4.64E-08	4.91E-08	4.19E-08	3.13E-08	2.18E-08	5.83E-09	5.15E-11*
8.4E+02	4.64E-08	4.90E-08	4.19E-08	3.13E-08	2.18E-08	5.83E-09	5.23E-11*
1.2E+03	4.64E-08	4.89E-08	4.19E-08	3.12E-08	2.18E-08	5.84E-09	5.29E-11*
2.4E+03	4.64E-08	4.87E-08	4.18E-08	3.12E-08	2.18E-08	5.85E-09	5.47E-11*
4.8E+03	4.64E-08	4.85E-08	4.17E-08	3.10E-08	2.19E-08	5.87E-09	5.73E-11*
8.4E+03	4.64E-08	4.81E-08	4.16E-08	3.08E-08	2.19E-08	5.91E-09	6.04E-11*
1.2E+04	4.63E-08	4.77E-08	4.14E-08	3.08E-08	2.19E-08	5.94E-09	6.31E-11*
2.0E+04	4.61E-08	4.71E-08	4.10E-08	3.05E-08	2.19E-08	6.02E-09	6.85E-11*

Accuracy: * - Possible Error Greater Than 10%
** - Possible Error Greater Than 100%

Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.2E+00 eV, E_{max} = 2.0E+04 eV

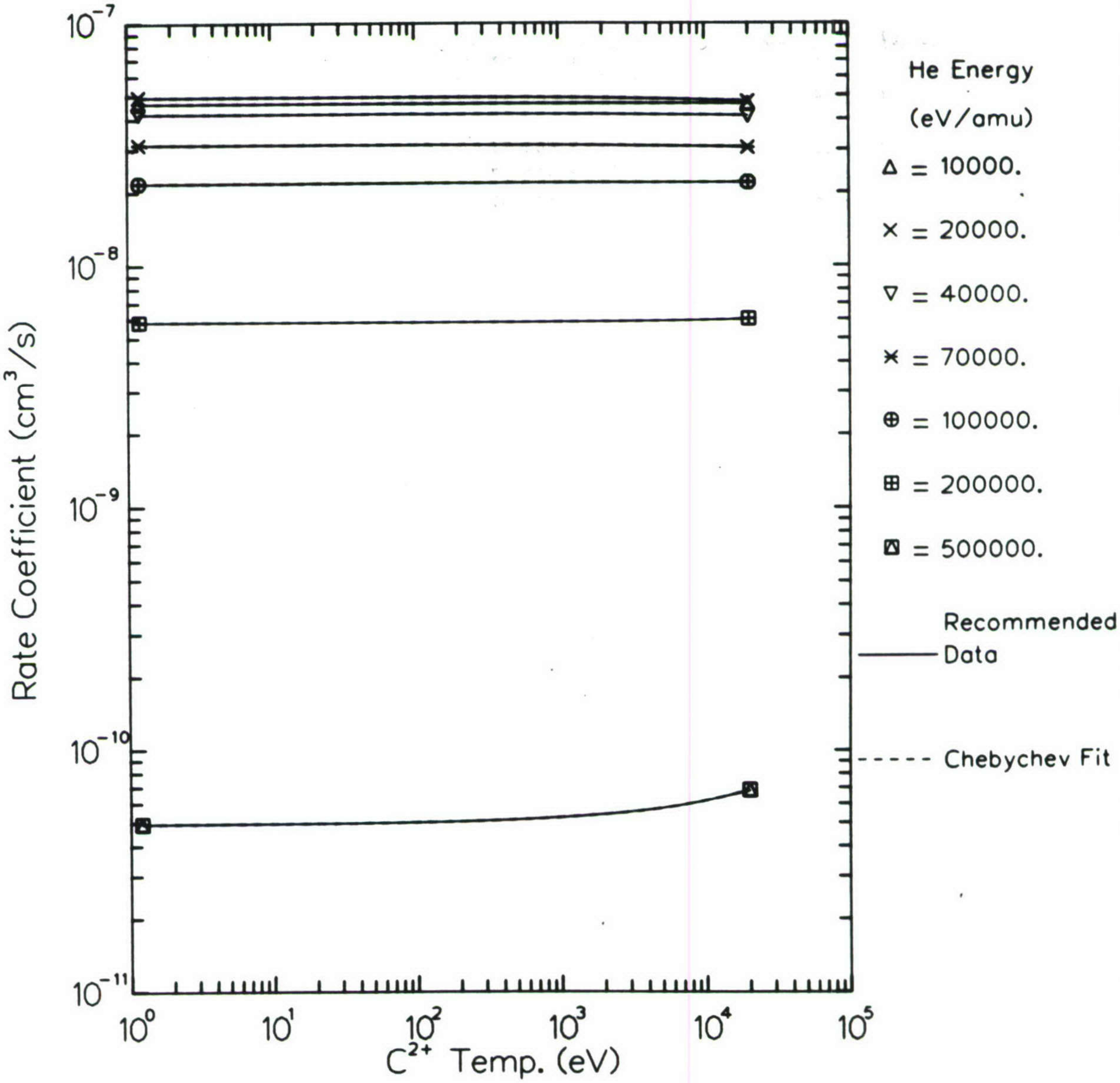
Chebychev Fitting Parameters for Rate Coefficients

He Energy (eV/amu)	C1	C2	C3	C4	C5	C6	C7
10000.	9.276E-08	-5.342E-11	-5.928E-11	-4.723E-11	-3.323E-11	-2.268E-11	-1.351E-11
20000.	9.756E-08	-8.456E-10	-4.792E-10	-2.143E-10	-8.248E-11	-3.048E-11	-1.151E-11
40000.	8.355E-08	-3.108E-10	-2.193E-10	-1.247E-10	-5.719E-11	-2.113E-11	-6.587E-12
70000.	6.234E-08	-3.494E-10	-2.020E-10	-9.245E-11	-3.491E-11	-1.057E-11	-2.199E-12
100000.	4.361E-08	8.407E-11	2.907E-11	-2.344E-12	-1.018E-11	-8.180E-12	-4.771E-12
200000.	1.172E-08	6.354E-11	4.596E-11	2.693E-11	1.295E-11	5.060E-12	1.515E-12
500000.	1.079E-10	7.606E-12	4.126E-12	1.769E-12	6.595E-13	2.272E-13	7.552E-14

See appendix for Chebychev fit details.

$He + C^{2+} \rightarrow C^{+} + He^{+}$

Beam – Maxwellian



Total Electron Capture Cross Sections for
$C^{3+} + He \rightarrow C^{2+} + He^{+}$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
1.0E+00	1.39E+06	1.56E-16
2.0E+00	1.96E+06	3.16E-16
4.0E+00	2.78E+06	4.94E-16
7.0E+00	3.68E+06	6.88E-16
1.0E+01	4.39E+06	8.33E-16
2.0E+01	6.21E+06	1.13E-15
4.0E+01	8.79E+06	1.37E-15
7.0E+01	1.16E+07	1.56E-15
1.0E+02	1.39E+07	1.65E-15
2.0E+02	1.96E+07	1.78E-15
4.0E+02	2.78E+07	1.79E-15
7.0E+02	3.68E+07	1.76E-15
1.0E+03	4.39E+07	1.69E-15
1.7E+03	5.66E+07	1.61E-15
2.0E+03	6.21E+07	1.56E-15
4.0E+03	8.79E+07	1.33E-15
7.0E+03	1.16E+08	1.11E-15
1.0E+04	1.39E+08	9.63E-16
2.0E+04	1.96E+08	6.74E-16
4.0E+04	2.78E+08	4.50E-16
7.0E+04	3.68E+08	2.68E-16
1.0E+05	4.39E+08	1.88E-16
2.0E+05	6.21E+08	6.72E-17
4.0E+05	8.78E+08	1.22E-17
7.0E+05	1.16E+09	7.77E-19

References: E.22, E.24, E.25, E.26, T.9, T.32

Accuracy: 30% for $2x10^2 \lesssim E(eV/amu) \lesssim 1x10^4$; 40% for $1x10^4 \lesssim E(eV/amu) \lesssim 4x10^5$; 100% for $1 \lesssim E(eV/amu) < 2x10^2$; 100% for $4x10^5 < E(eV/amu) < 1x10^6$

Notes: (1) According to two-state Landau-Zener calculations [T.32] (having an accuracy of 100%), the cross section for E < 1 eV/amu continues to decrease, reaching values of $6x10^{-18}$ cm^2 at E = 0.1 eV/amu, and $7x10^{-19}$ cm^2 at $2x10^{-2}$ eV/amu.

(2) In the region below $E = 1.0x10^4$ eV/amu, the $C^{2+}(2s2p)\,^1P^0$ final (metastable) state is dominantly populated, while for energies above ~ $2x10^4$ eV/amu a significant contribution to σ comes also from capture to $(2s2p)\,^3P^0$, and $(2p^2)$ ^3P, ^1D excited states of C^{2+}, [E.24], [E.27].

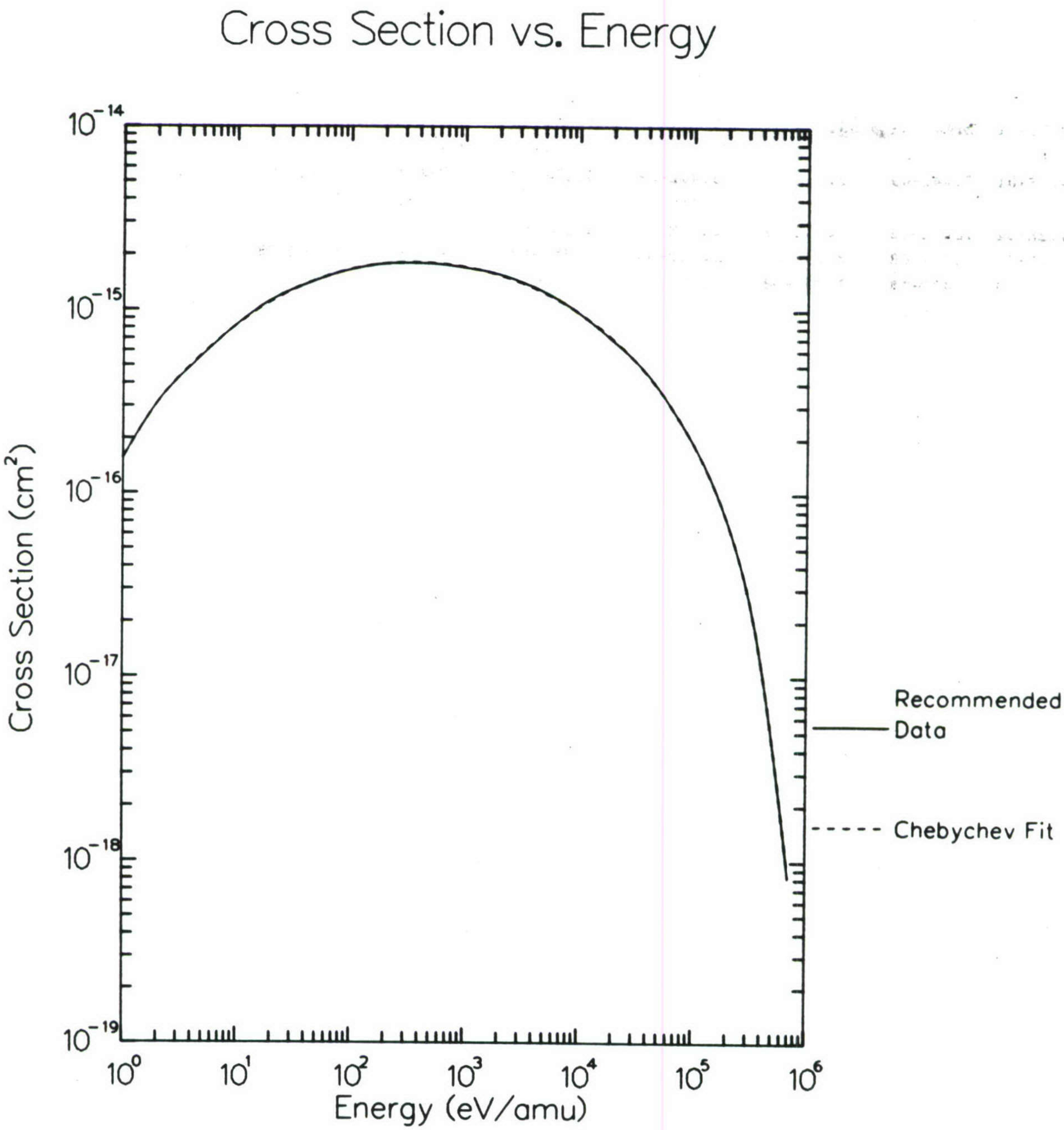
For Chebychev fits of the above cross sections it is necessary to use the following parameters.
E_{min} = 1.0E+00 eV/amu, E_{max} = 7.0E+05 eV/amu

Chebychev Fitting Parameters for Cross Sections

C1	C2	C3	C4	C5	C6	C7	C8	C9
1.363E-15	-2.279E-16	-8.005E-16	1.862E-16	2.321E-16	-4.510E-17	-3.149E-17	9.203E-18	-3.221E-18

The fit represents the above cross sections with an rms deviation of 1.1%.
The maximum deviation is 2.3% at 2.0E+04 eV/amu.
See appendix for Chebychev fit details.

$C^{3+} + He \rightarrow C^{2+} + He^{+}$



Total Electron Capture Rate Coefficients for
$C^{3+} + He \rightarrow C^{2+} + He^{+}$

Maxwellian - Maxwellian Rate Coefficients (cm^3/s)

C^{3+} Temp. (eV)	Equal Temp.	He Temp. (eV) 1.	10.	100.	1000.	5000.	10000.	20000.
1.0E+00	9.08E-11	9.07E-11	1.33E-09	1.05E-08	4.31E-08	8.41E-08	1.03E-07	1.17E-07
1.2E+00	1.20E-10	9.78E-11	1.34E-09	1.05E-08	4.31E-08	8.41E-08	1.03E-07	1.17E-07
2.4E+00	3.26E-10	1.44E-10	1.40E-09	1.06E-08	4.31E-08	8.41E-08	1.03E-07	1.17E-07
4.8E+00	7.74E-10	2.45E-10	1.51E-09	1.06E-08	4.32E-08	8.41E-08	1.03E-07	1.17E-07
8.4E+00	1.45E-09	4.08E-10	1.67E-09	1.07E-08	4.32E-08	8.41E-08	1.03E-07	1.17E-07
1.2E+01	2.11E-09	5.76E-10	1.84E-09	1.08E-08	4.32E-08	8.41E-08	1.03E-07	1.17E-07
2.4E+01	4.12E-09	1.14E-09	2.38E-09	1.11E-08	4.33E-08	8.42E-08	1.03E-07	1.17E-07
4.8E+01	7.44E-09	2.24E-09	3.40E-09	1.17E-08	4.35E-08	8.42E-08	1.03E-07	1.17E-07
8.4E+01	1.14E-08	3.76E-09	4.80E-09	1.26E-08	4.37E-08	8.43E-08	1.03E-07	1.17E-07
1.2E+02	1.47E-08	5.13E-09	6.08E-09	1.34E-08	4.40E-08	8.43E-08	1.03E-07	1.17E-07
2.4E+02	2.31E-08	8.95E-09	9.70E-09	1.59E-08	4.48E-08	8.46E-08	1.03E-07	1.17E-07
4.8E+02	3.43E-08	1.48E-08	1.53E-08	2.03E-08	4.63E-08	8.50E-08	1.03E-07	1.17E-07
8.4E+02	4.56E-08	2.13E-08	2.17E-08	2.56E-08	4.85E-08	8.56E-08	1.03E-07	1.17E-07
1.2E+03	5.38E-08	2.64E-08	2.67E-08	3.00E-08	5.06E-08	8.63E-08	1.04E-07	1.18E-07
2.4E+03	7.17E-08	3.86E-08	3.88E-08	4.09E-08	5.67E-08	8.82E-08	1.05E-07	1.18E-07
4.8E+03	9.09E-08	5.38E-08	5.39E-08	5.53E-08	6.61E-08	9.18E-08	1.06E-07	1.18E-07
8.4E+03	1.05E-07	6.81E-08	6.82E-08	6.91E-08	7.65E-08	9.63E-08	1.08E-07	1.19E-07
1.2E+04	1.13E-07	7.79E-08	7.80E-08	7.86E-08	8.41E-08	1.00E-07	1.10E-07	1.20E-07
2.0E+04	1.21E-07	9.19E-08	9.20E-08	9.24E-08	9.57E-08	1.06E-07	1.14E-07	1.21E-07

Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

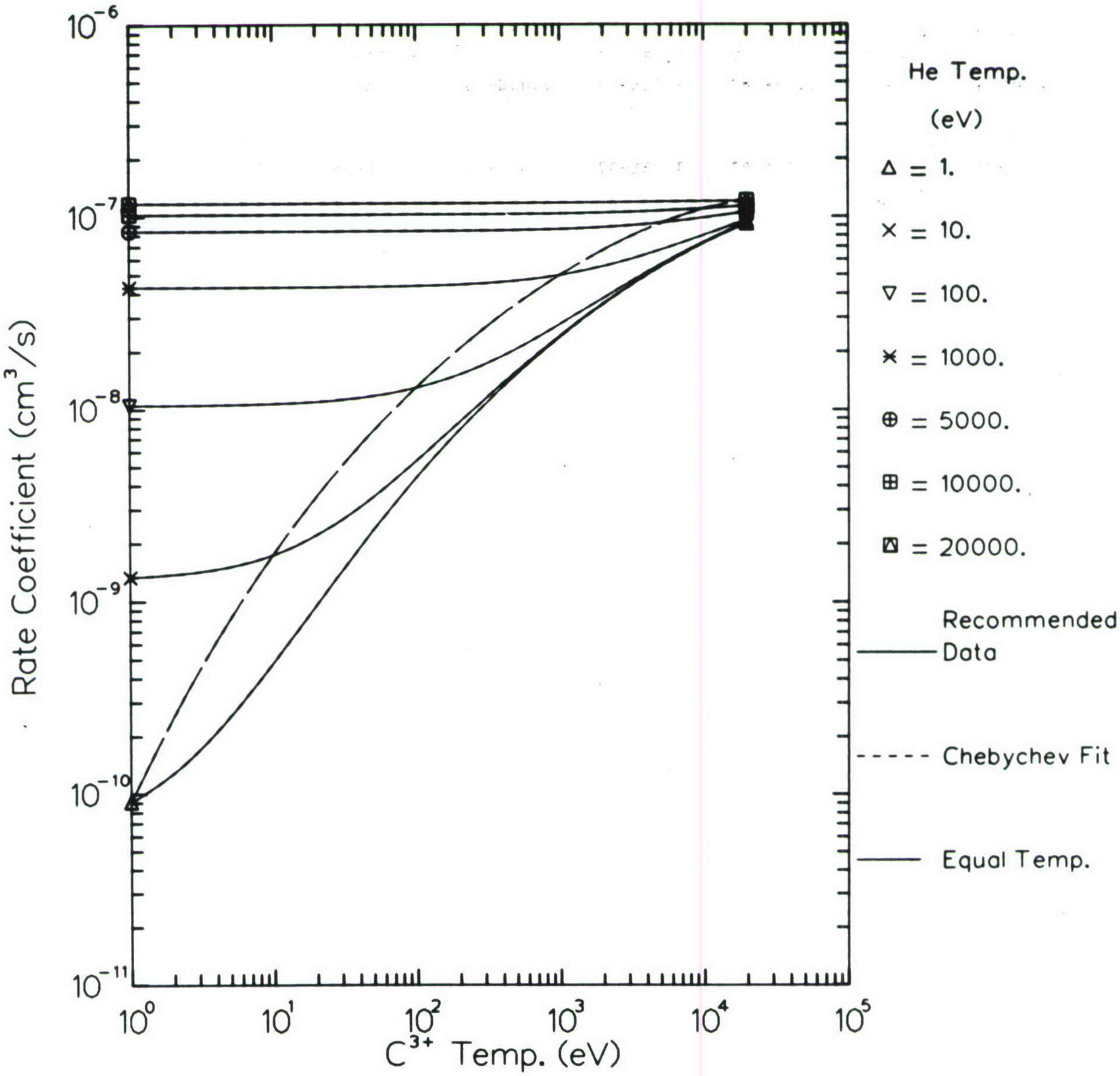
Chebychev Fitting Parameters for Rate Coefficients

He Temp. (eV)	C1	C2	C3	C4	C5	C6	C7
1.	5.269E-08	4.175E-08	2.030E-08	4.953E-09	-2.819E-10	-5.462E-10	-1.174E-10
10.	5.415E-08	4.103E-08	2.014E-08	5.024E-09	-3.186E-10	-6.452E-10	-1.617E-10
100.	6.528E-08	3.606E-08	1.908E-08	5.645E-09	1.992E-11	-7.424E-10	-2.695E-10
1000.	1.113E-07	2.123E-08	1.302E-08	5.433E-09	1.173E-09	-2.174E-10	-3.061E-10
5000.	1.777E-07	8.254E-09	5.472E-09	2.721E-09	9.535E-10	1.753E-10	-5.166E-11
10000.	2.100E-07	4.075E-09	2.757E-09	1.432E-09	5.510E-10	1.357E-10	-5.782E-12
20000.	2.360E-07	1.462E-09	1.003E-09	5.376E-10	2.217E-10	6.535E-11	7.578E-12
Equal Temp.	8.387E-08	6.190E-08	2.244E-08	2.481E-10	-3.237E-09	-1.281E-09	-1.829E-10

See appendix for Chebychev fit details.

$C^{3+} + He \rightarrow C^{2+} + He^{+}$

Maxwellian — Maxwellian



Total Electron Capture Rate Coefficients for
$He + C^{3+} \rightarrow C^{2+} + He^{+}$

Beam - Maxwellian Rate Coefficients (cm^3/s)

C^{3+} Temp. (eV)	He Energy (eV/amu) 10000.	20000.	40000.	70000.	100000.	200000.	500000.
1.0E+00	1.34E-07	1.32E-07	1.25E-07	9.85E-08	8.26E-08	4.17E-08	4.63E-09
1.2E+00	1.34E-07	1.32E-07	1.25E-07	9.85E-08	8.26E-08	4.17E-08	4.63E-09
2.4E+00	1.34E-07	1.32E-07	1.25E-07	9.85E-08	8.26E-08	4.17E-08	4.63E-09
4.8E+00	1.34E-07	1.32E-07	1.25E-07	9.85E-08	8.26E-08	4.17E-08	4.63E-09
8.4E+00	1.34E-07	1.32E-07	1.25E-07	9.85E-08	8.26E-08	4.17E-08	4.63E-09
1.2E+01	1.34E-07	1.32E-07	1.25E-07	9.85E-08	8.26E-08	4.17E-08	4.63E-09
2.4E+01	1.34E-07	1.32E-07	1.25E-07	9.85E-08	8.25E-08	4.17E-08	4.63E-09
4.8E+01	1.34E-07	1.32E-07	1.25E-07	9.85E-08	8.25E-08	4.17E-08	4.63E-09
8.4E+01	1.34E-07	1.32E-07	1.25E-07	9.86E-08	8.25E-08	4.17E-08	4.63E-09
1.2E+02	1.34E-07	1.32E-07	1.25E-07	9.86E-08	8.25E-08	4.17E-08	4.63E-09
2.4E+02	1.34E-07	1.32E-07	1.25E-07	9.86E-08	8.25E-08	4.17E-08	4.63E-09
4.8E+02	1.34E-07	1.32E-07	1.25E-07	9.86E-08	8.24E-08	4.17E-08	4.63E-09
8.4E+02	1.34E-07	1.33E-07	1.24E-07	9.87E-08	8.24E-08	4.17E-08	4.64E-09
1.2E+03	1.33E-07	1.33E-07	1.24E-07	9.87E-08	8.23E-08	4.17E-08	4.64E-09
2.4E+03	1.33E-07	1.32E-07	1.24E-07	9.87E-08	8.21E-08	4.16E-08	4.65E-09
4.8E+03	1.33E-07	1.32E-07	1.23E-07	9.88E-08	8.20E-08	4.15E-08	4.67E-09
8.4E+03	1.32E-07	1.32E-07	1.23E-07	9.86E-08	8.18E-08	4.15E-08	4.70E-09
1.2E+04	1.32E-07	1.32E-07	1.22E-07	9.87E-08	8.15E-08	4.15E-08	4.74E-09
2.0E+04	1.30E-07	1.31E-07	1.21E-07	9.84E-08	8.12E-08	4.14E-08	4.81E-09

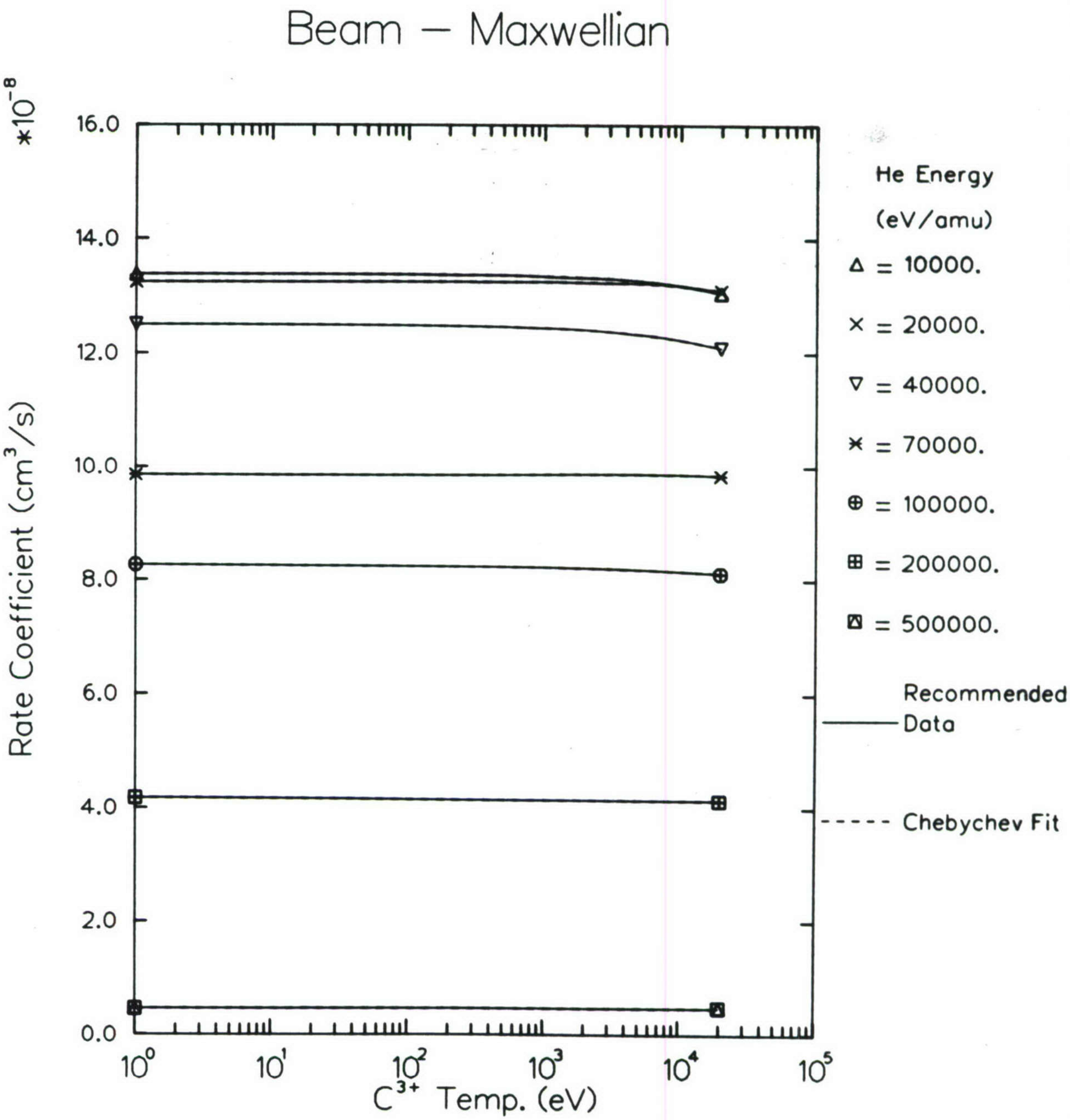
Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

Chebychev Fitting Parameters for Rate Coefficients

He Energy (eV/amu)	C1	C2	C3	C4	C5	C6	C7
10000.	2.662E-07	-1.192E-09	-7.627E-10	-3.817E-10	-1.612E-10	-6.320E-11	-2.024E-11
20000.	2.644E-07	-4.364E-10	-3.744E-10	-2.506E-10	-1.386E-10	-6.899E-11	-3.345E-11
40000.	2.481E-07	-1.579E-09	-9.183E-10	-4.160E-10	-1.500E-10	-4.042E-11	-5.180E-12
70000.	1.971E-07	6.193E-11	-4.504E-11	-7.575E-11	-5.535E-11	-2.743E-11	-1.156E-11
100000.	1.645E-07	-5.572E-10	-3.182E-10	-1.388E-10	-4.633E-11	-1.051E-11	7.877E-13
200000.	8.330E-08	-1.413E-10	-6.817E-11	-2.345E-11	-4.644E-12	-5.334E-13	-9.742E-13
500000.	9.323E-09	5.830E-11	4.166E-11	2.455E-11	1.214E-11	5.049E-12	1.895E-12

See appendix for Chebychev fit details.

$He + C^{3+} \rightarrow C^{2+} + He^{+}$



Total Electron Capture Cross Sections for
$C^{4+} + He \rightarrow C^{3+} + He^{+}$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
4.0E+01	8.79E+06	1.34E-17
7.0E+01	1.16E+07	2.05E-17
1.0E+02	1.39E+07	2.68E-17
2.0E+02	1.96E+07	4.38E-17
4.0E+02	2.78E+07	7.29E-17
7.0E+02	3.68E+07	1.10E-16
1.0E+03	4.39E+07	1.41E-16
1.7E+03	5.66E+07	2.00E-16
2.0E+03	6.21E+07	2.27E-16
4.0E+03	8.79E+07	3.39E-16
7.0E+03	1.16E+08	4.25E-16
1.0E+04	1.39E+08	4.69E-16
2.0E+04	1.96E+08	5.15E-16
4.0E+04	2.78E+08	4.95E-16
7.0E+04	3.68E+08	4.27E-16
1.0E+05	4.39E+08	3.58E-16
2.0E+05	6.21E+08	1.39E-16
4.0E+05	8.78E+08	2.25E-17

References: E.22, E.25, E.26, E.28, E.29, E.30, T.9, T.39

Accuracy: 40% for $40 \lesssim E(\text{eV/amu}) \lesssim 2\times10^4$; 50% for $2\times10^4 < E(\text{eV/amu}) < 4\times10^5$

Notes: (1) Theoretical estimates of the cross section, [T.32] in the region ~ 5×10^{-2} eV/amu, based on the Landau-Zener model, predict a cross section on the order of 10^{-19} cm^2.

(2) In the region $3\times10^2 \lesssim E(\text{eV/amu}) \lesssim 3\times10^4$, the dominantly populated final state is $C^{3+}(2p)$, [T.39], [E.32], while at higher energies capture to $C^{3+}(2s)$ is expected to dominate. (Note that significant population of the 3d and 3p final states was observed [E.31] at $E \simeq (5-7)\times10^4$ eV/amu).

(3) For energies below ~ 10^3 eV/amu, double electron capture in C^{4+} + He collisions is the dominant reaction channel (at least down to ~ 200 eV/amu) [E.29], [T.39].

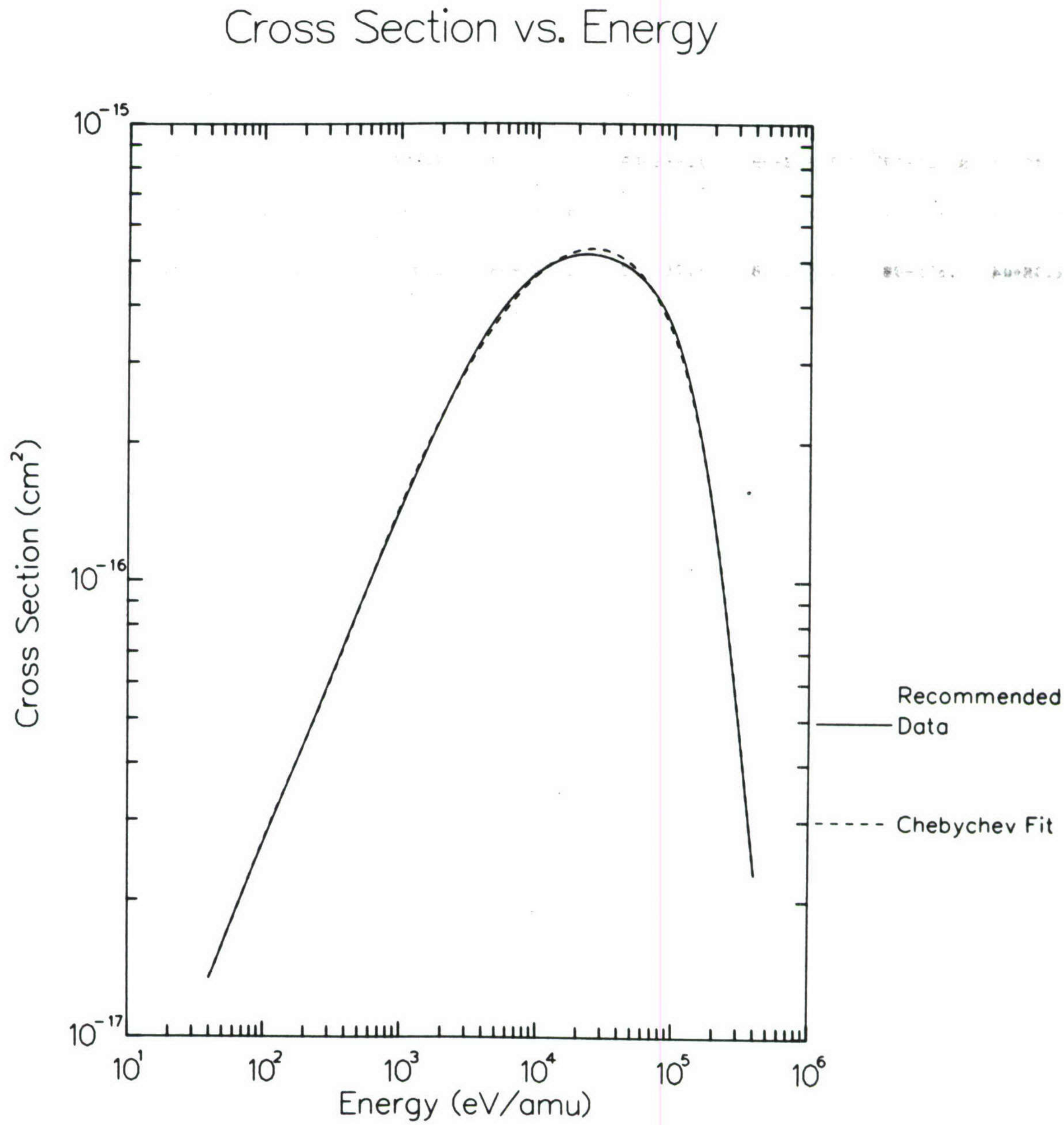
For Chebychev fits of the above cross sections it is necessary to use the following parameters.
E_{min} = 4.0E+01 eV/amu, E_{max} = 4.0E+05 eV/amu

Chebychev Fitting Parameters for Cross Sections

C1	C2	C3	C4	C5	C6	C7	C8	C9
3.576E-16	1.029E-16	-1.782E-16	-1.449E-16	-5.211E-18	4.230E-17	2.165E-17	4.277E-18	9.385E-19

The fit represents the above cross sections with an rms deviation of 1.6%.
The maximum deviation is 3.3% at 4.0E+04 eV/amu.
See appendix for Chebychev fit details.

$C^{4+} + He \rightarrow C^{3+} + He^{+}$



Total Electron Capture Rate Coefficients for
$C^{4+} + He \rightarrow C^{3+} + He^{+}$

Maxwellian - Maxwellian Rate Coefficients (cm^3/s)

C^{4+} Temp. (eV)	Equal Temp.	He Temp. (eV) 1.	10.	100.	1000.	5000.	10000.	20000.
6.0E+01	8.88E-11	1.48E-11*	2.45E-11	1.48E-10	2.07E-09	1.31E-08	2.60E-08	4.63E-08
1.2E+02	2.13E-10	3.73E-11	4.84E-11	1.80E-10	2.12E-09	1.32E-08	2.61E-08	4.63E-08
2.4E+02	5.00E-10	9.03E-11	1.03E-10	2.46E-10	2.22E-09	1.33E-08	2.62E-08	4.64E-08
4.8E+02	1.17E-09	2.14E-10	2.29E-10	3.87E-10	2.42E-09	1.35E-08	2.64E-08	4.66E-08
8.4E+02	2.32E-09	4.26E-10	4.43E-10	6.17E-10	2.73E-09	1.39E-08	2.66E-08	4.68E-08
1.2E+03	3.56E-09	6.59E-10	6.78E-10	8.65E-10	3.04E-09	1.42E-08	2.69E-08	4.70E-08
2.4E+03	8.02E-09	1.54E-09	1.56E-09	1.78E-09	4.10E-09	1.53E-08	2.79E-08	4.76E-08
4.8E+03	1.69E-08	3.57E-09	3.59E-09	3.83E-09	6.32E-09	1.74E-08	2.97E-08	4.90E-08
8.4E+03	2.88E-08	6.89E-09	6.91E-09	7.17E-09	9.72E-09	2.06E-08	3.23E-08	5.10E-08
1.2E+04	3.89E-08	1.03E-08	1.03E-08	1.06E-08	1.31E-08	2.36E-08	3.49E-08	5.29E-08
2.0E+04	5.67E-08	1.75E-08	1.76E-08	1.78E-08	2.01E-08	2.98E-08	4.01E-08	5.68E-08

Accuracy: * - Possible Error Greater Than 10%
** - Possible Error Greater Than 100%

Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 6.0E+01 eV, E_{max} = 2.0E+04 eV

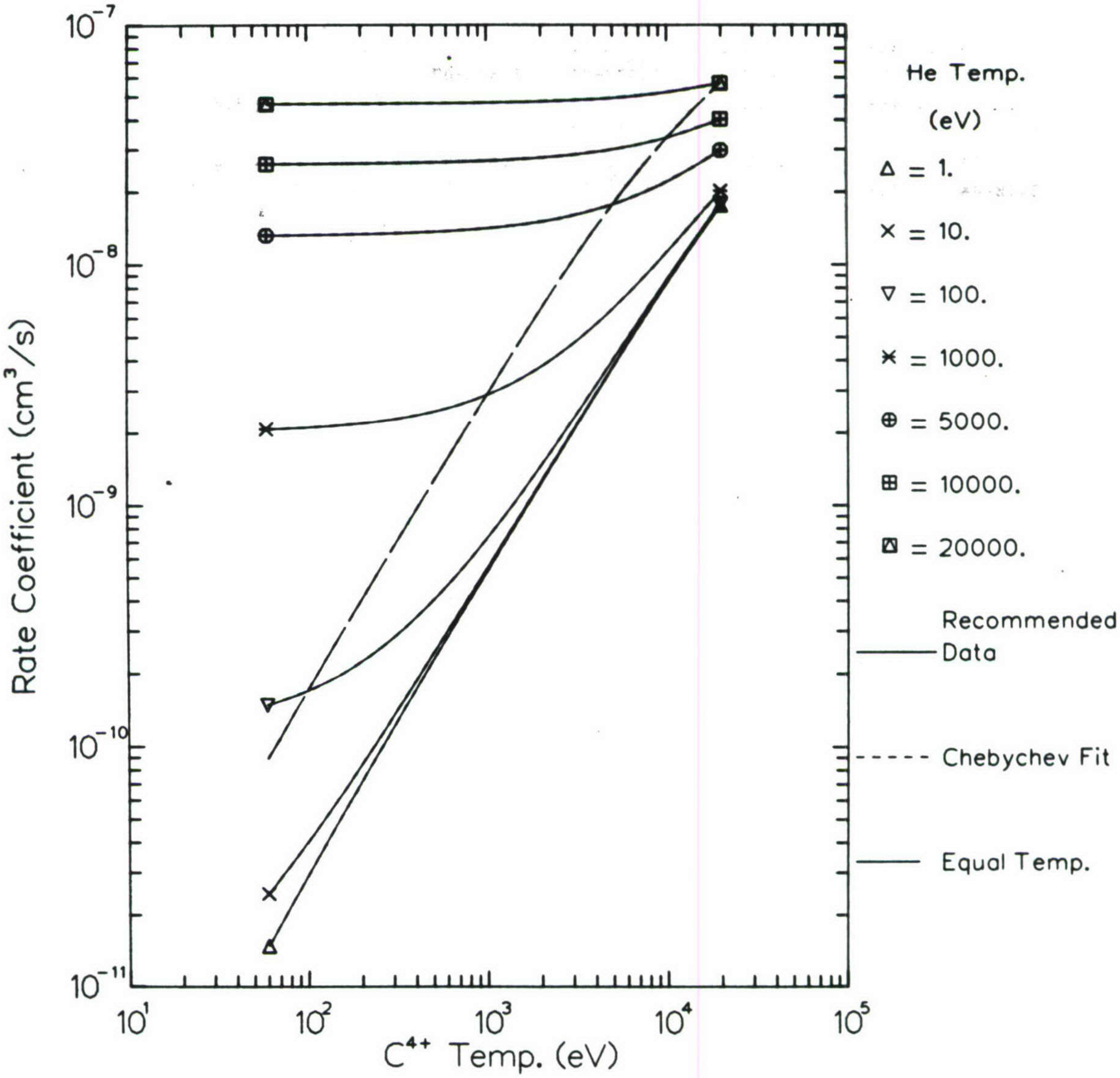
Chebychev Fitting Parameters for Rate Coefficients

He Temp. (eV)	C1	C2	C3	C4	C5	C6	C7
1.	8.211E-09	6.849E-09	4.094E-09	1.811E-09	5.923E-10	1.341E-10	1.634E-11
10.	8.247E-09	6.857E-09	4.093E-09	1.809E-09	5.916E-10	1.338E-10	1.631E-11
100.	8.623E-09	6.927E-09	4.091E-09	1.795E-09	5.840E-10	1.313E-10	1.570E-11
1000.	1.301E-08	7.243E-09	4.076E-09	1.691E-09	5.232E-10	1.115E-10	1.044E-11
5000.	3.472E-08	6.782E-09	3.668E-09	1.438E-09	4.185E-10	8.659E-11	9.123E-12
10000.	5.921E-08	5.756E-09	3.113E-09	1.222E-09	3.575E-10	7.459E-11	8.027E-12
20000.	9.792E-08	4.276E-09	2.326E-09	9.209E-10	2.716E-10	5.540E-11	3.584E-12
Equal Temp.	3.047E-08	2.436E-08	1.272E-08	4.152E-09	5.843E-10	-1.472E-10	-8.263E-11

See appendix for Chebychev fit details.

$C^{4+} + He \rightarrow C^{3+} + He^{+}$

Maxwellian – Maxwellian



Total Electron Capture Rate Coefficients for
$He + C^{4+} \rightarrow C^{3+} + He^{+}$

Beam - Maxwellian Rate Coefficients (cm^3/s)

C^{4+} Temp. (eV)	He Energy (eV/amu) 10000.	20000.	40000.	70000.	100000.	200000.	500000.
6.0E+01	6.52E-08	1.01E-07	1.38E-07	1.57E-07	1.57E-07	8.63E-08	7.81E-09
1.2E+02	6.52E-08	1.01E-07	1.37E-07	1.57E-07	1.57E-07	8.63E-08	7.81E-09
2.4E+02	6.52E-08	1.01E-07	1.37E-07	1.57E-07	1.57E-07	8.63E-08	7.81E-09
4.8E+02	6.53E-08	1.01E-07	1.37E-07	1.57E-07	1.57E-07	8.63E-08	7.81E-09
8.4E+02	6.54E-08	1.01E-07	1.37E-07	1.57E-07	1.57E-07	8.63E-08	7.82E-09
1.2E+03	6.56E-08	1.01E-07	1.37E-07	1.57E-07	1.56E-07	8.63E-08	7.83E-09
2.4E+03	6.60E-08	1.01E-07	1.37E-07	1.57E-07	1.56E-07	8.62E-08	7.85E-09
4.8E+03	6.65E-08	1.02E-07	1.37E-07	1.56E-07	1.55E-07	8.61E-08	7.90E-09
8.4E+03	6.77E-08	1.02E-07	1.37E-07	1.56E-07	1.55E-07	8.61E-08	7.96E-09
1.2E+04	6.90E-08	1.02E-07	1.37E-07	1.56E-07	1.54E-07	8.60E-08	8.04E-09
2.0E+04	7.18E-08	1.03E-07	1.37E-07	1.55E-07	1.52E-07	8.58E-08	8.19E-09

Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 6.0E+01 eV, E_{max} = 2.0E+04 eV

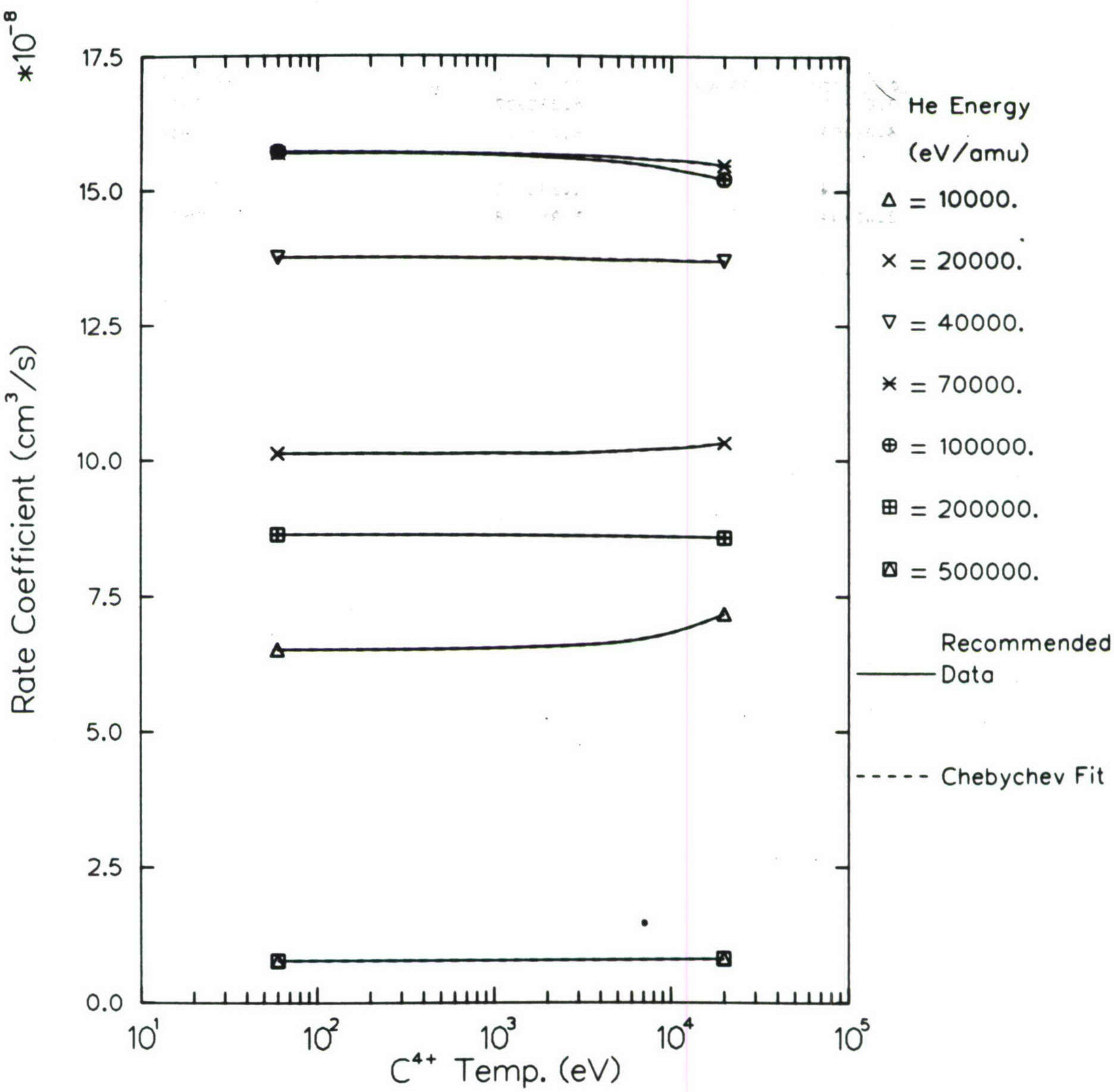
Chebychev Fitting Parameters for Rate Coefficients

He Energy (eV/amu)	C1	C2	C3	C4	C5	C6	C7
10000.	1.335E-07	2.562E-09	1.476E-09	6.649E-10	2.620E-10	7.905E-11	-1.245E-11
20000.	2.033E-07	8.108E-10	4.783E-10	2.054E-10	5.913E-11	1.391E-11	1.698E-11
40000.	2.746E-07	-2.837E-10	-9.655E-11	5.917E-13	2.454E-11	1.737E-11	2.380E-12
70000.	3.126E-07	-9.092E-10	-4.406E-10	-1.728E-10	-5.148E-11	-1.389E-11	-2.379E-11
100000.	3.113E-07	-2.176E-09	-9.715E-10	-3.084E-10	-7.810E-11	-1.172E-11	3.300E-11
200000.	1.724E-07	-2.180E-10	-9.012E-11	-2.979E-11	-1.014E-11	-9.096E-12	-1.294E-11
500000.	1.580E-08	1.529E-10	8.516E-11	3.558E-11	1.187E-11	3.261E-12	5.536E-13

See appendix for Chebychev fit details.

$He + C^{4+} \rightarrow C^{3+} + He^{+}$

Beam – Maxwellian



Total Double Electron Capture Cross Sections for
$C^{4+} + He \rightarrow C^{2+} + He^{2+}$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
3.0E+01	7.61E+06	7.00E-17
4.0E+01	8.79E+06	1.00E-16
7.0E+01	1.16E+07	1.85E-16
1.0E+02	1.39E+07	2.50E-16
2.0E+02	1.96E+07	3.40E-16
4.0E+02	2.78E+07	3.50E-16
7.0E+02	3.68E+07	3.30E-16
1.0E+03	4.39E+07	3.10E-16
2.0E+03	6.21E+07	2.55E-16
4.0E+03	8.79E+07	2.10E-16
7.0E+03	1.16E+08	1.90E-16
1.0E+04	1.39E+08	1.70E-16
2.0E+04	1.96E+08	1.20E-16
4.0E+04	2.78E+08	5.20E-17
7.0E+04	3.68E+08	1.60E-17
1.0E+05	4.39E+08	7.20E-18
2.0E+05	6.21E+08	1.40E-18
4.0E+05	8.78E+08	2.50E-19
5.0E+05	9.82E+08	1.20E-19
6.0E+05	1.08E+09	6.80E-20

References: E.25, E.28, E.29, E.30, E.89, T.39, T.114

Accuracy: 30% for 30 < E(eV/amu) < 100; 20% for 100 $\leq$ E(eV/amu) $\leq$ $1x10^4$; 100% for $1x10^4$ < E(eV/amu) < $3x10^5$; 30% for $3x10^5$ < E(eV/amu) < $4x10^5$

Notes: (1) This double electron capture reaction is unique in that the cross section exceeds that for single electron capture at energies below 2 keV/amu (by more than an order of magnitude for E < 200 eV/amu).
(2) At energies E < $2x10^4$ eV/amu, double capture occurs exclusively into the $1s^22s^2(^1S_0)$ ground state of C^{2+} [E.89,T.39], and this product channel is expected to dominate at higher energies as well.
(3) The cross section at energies between $1x10^4$ and $3x10^5$ eV/amu has been obtained by interpolation, and has an estimated uncertainty of 100%.

For Chebychev fits of the above cross sections it is necessary to use the following parameters.
E_{min} = 3.0E+01 eV/amu, E_{max} = 6.0E+05 eV/amu

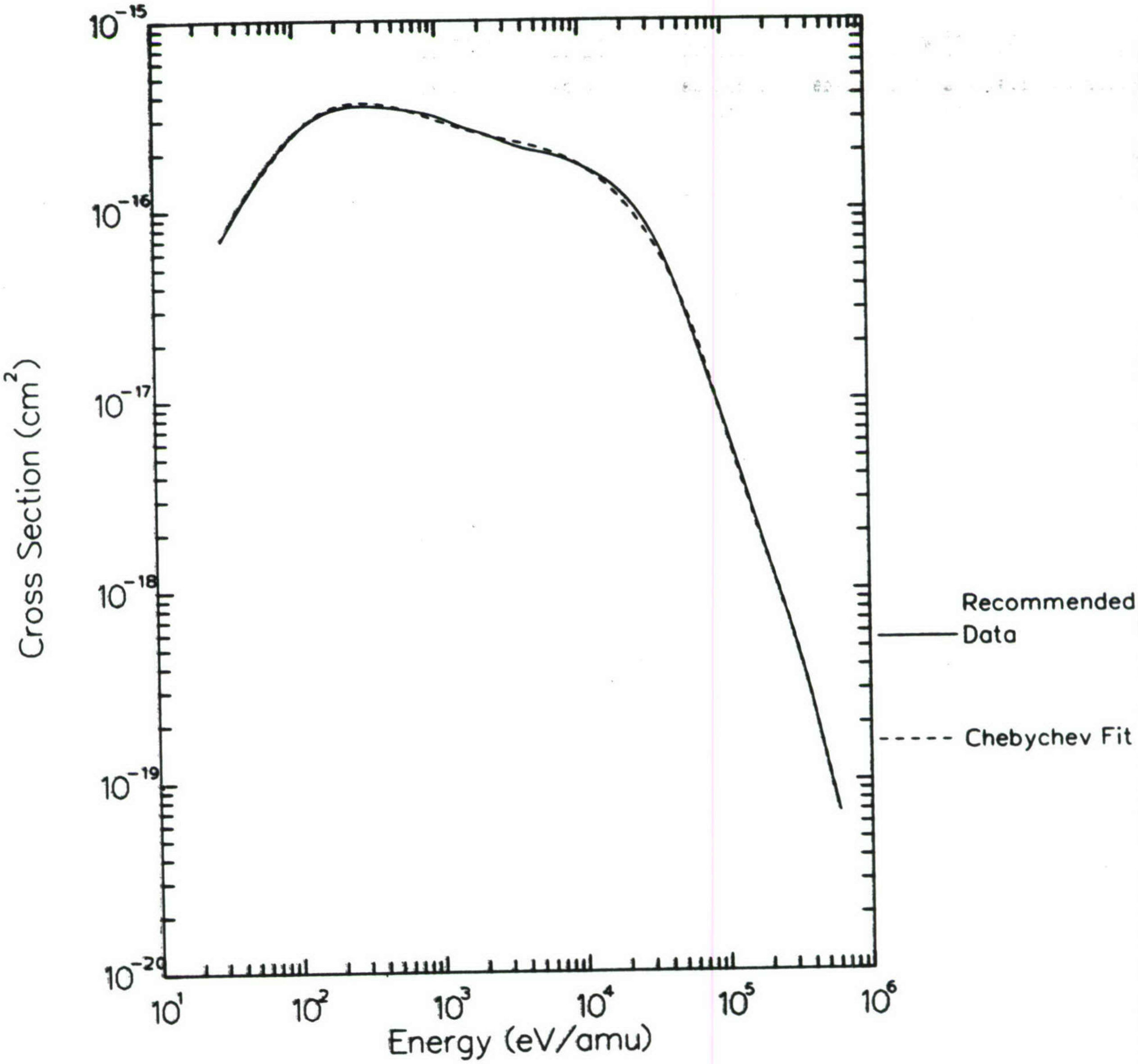
Chebychev Fitting Parameters for Cross Sections

C1	C2	C3	C4	C5	C6	C7	C8	C9
2.681E-16	-1.099E-16	-9.925E-17	9.065E-17	-1.019E-17	-5.452E-18	1.070E-17	-1.853E-17	3.581E-18

The fit represents the above cross sections with an rms deviation of 3.5%.
The maximum deviation is 8.1% at 7.0E+04 eV/amu.
See appendix for Chebychev fit details.

$C^{4+} + He \rightarrow C^{2+} + He^{2+}$

Cross Section vs. Energy



Total Double Electron Capture Rate Coefficients for $C^{4+} + He \rightarrow C^{2+} + He^{2+}$

Maxwellian - Maxwellian Rate Coefficients (cm^3/s)

C^{4+} Temp. (eV)	Equal Temp.	He Temp. (eV) 1.	10.	100.	1000.	5000.	10000.	20000.
3.6E+02	5.09E-09	1.15E-09*	1.28E-09*	2.51E-09	8.44E-09	1.44E-08	1.73E-08	1.99E-08
4.8E+02	6.20E-09	1.72E-09	1.85E-09	2.99E-09	8.58E-09	1.45E-08	1.73E-08	1.99E-08
8.4E+02	8.44E-09	3.23E-09	3.33E-09	4.24E-09	8.98E-09	1.45E-08	1.73E-08	1.99E-08
1.2E+03	9.88E-09	4.43E-09	4.51E-09	5.25E-09	9.34E-09	1.46E-08	1.74E-08	1.99E-08
2.4E+03	1.26E-08	7.09E-09	7.13E-09	7.56E-09	1.03E-08	1.49E-08	1.75E-08	2.00E-08
4.8E+03	1.53E-08	9.88E-09	9.90E-09	1.01E-08	1.18E-08	1.55E-08	1.78E-08	2.01E-08
8.4E+03	1.77E-08	1.21E-08	1.21E-08	1.22E-08	1.33E-08	1.61E-08	1.82E-08	2.02E-08
1.2E+04	1.91E-08	1.35E-08	1.35E-08	1.36E-08	1.43E-08	1.68E-08	1.86E-08	2.04E-08
2.0E+04	2.06E-08	1.55E-08	1.55E-08	1.55E-08	1.61E-08	1.78E-08	1.93E-08	2.06E-08

Accuracy: * - Possible Error Greater Than 10%
** - Possible Error Greater Than 100%

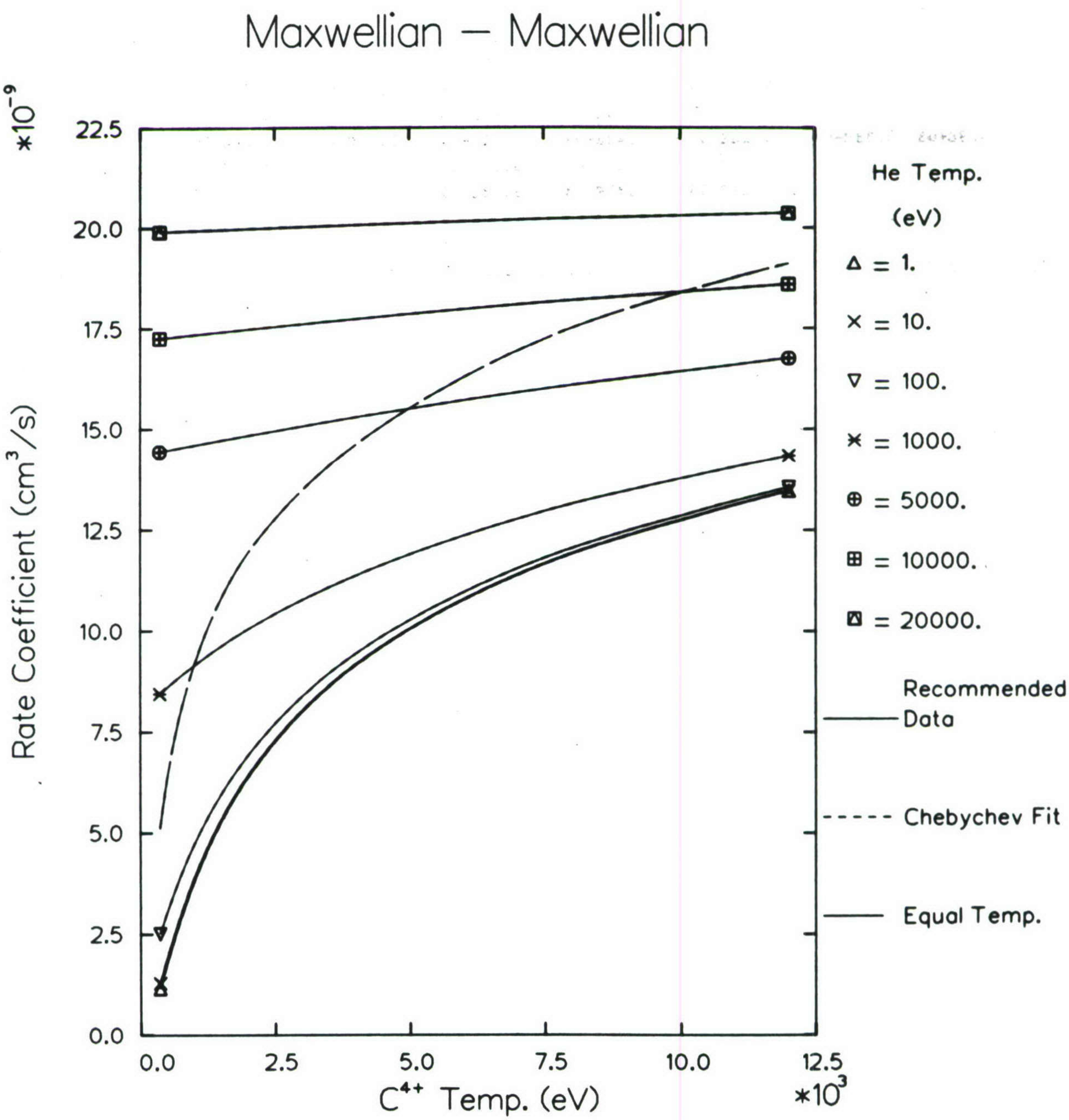
Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 3.6E+02 eV, E_{max} = 2.0E+04 eV

Chebychev Fitting Parameters for Rate Coefficients

He Temp. (eV)	C1	C2	C3	C4	C5	C6	C7
1.	1.573E-08	7.355E-09	3.952E-10	-2.115E-10	5.764E-11	1.852E-11	-1.498E-12
10.	1.584E-08	7.287E-09	4.088E-10	-2.068E-10	5.399E-11	1.934E-11	-1.262E-12
100.	1.692E-08	6.664E-09	5.340E-10	-1.708E-10	2.962E-11	2.285E-11	9.481E-13
1000.	2.283E-08	3.779E-09	8.502E-10	2.375E-11	-1.417E-11	5.762E-12	2.671E-12
5000.	3.111E-08	1.598E-09	5.741E-10	1.155E-10	5.506E-12	-4.654E-12	-1.658E-12
10000.	3.580E-08	9.291E-10	3.463E-10	7.602E-11	6.884E-12	-2.054E-12	-1.648E-12
20000.	4.023E-08	3.140E-10	1.107E-10	1.924E-11	-1.710E-12	-2.393E-12	-8.219E-13
Equal Temp.	2.602E-08	7.898E-09	-8.092E-11	-9.314E-11	-8.992E-11	-7.670E-11	-1.581E-11

See appendix for Chebychev fit details.

$C^{4+} + He -> C^{2+} + He^{2+}$



Maxwellian — Maxwellian
*10^-9
22.5
20.0
17.5
15.0
12.5
10.0
7.5
5.0
2.5
0.0
Rate Coefficient (cm^3/s)
0.0
2.5
5.0
7.5
10.0
12.5
C^4+ Temp. (eV)
*10^3
He Temp.
(eV)
Δ = 1.
× = 10.
∇ = 100.
✶ = 1000.
⊕ = 5000.
⊞ = 10000.
⊠ = 20000.
Recommended Data
Chebychev Fit
Equal Temp.

Total Double Electron Capture Rate Coefficients for
$He + C^{4+} \rightarrow C^{2+} + He^{2+}$

Beam - Maxwellian Rate Coefficients (cm^3/s)

C^{4+} Temp. (eV)	He Energy (eV/amu) 10000.	20000.	40000.	70000.	100000.	200000.	500000.
3.6E+02	2.36E-08	2.34E-08	1.44E-08	5.91E-09	3.16E-09	8.70E-10	1.18E-10
4.8E+02	2.36E-08	2.34E-08	1.44E-08	5.91E-09	3.17E-09	8.70E-10	1.18E-10
8.4E+02	2.36E-08	2.33E-08	1.44E-08	5.92E-09	3.17E-09	8.71E-10	1.18E-10
1.2E+03	2.35E-08	2.33E-08	1.44E-08	5.93E-09	3.17E-09	8.71E-10	1.18E-10
2.4E+03	2.35E-08	2.31E-08	1.43E-08	5.96E-09	3.17E-09	8.72E-10	1.19E-10
4.8E+03	2.33E-08	2.28E-08	1.42E-08	6.01E-09	3.19E-09	8.74E-10	1.19E-10
8.4E+03	2.31E-08	2.25E-08	1.42E-08	6.07E-09	3.21E-09	8.78E-10	1.20E-10
1.2E+04	2.30E-08	2.21E-08	1.41E-08	6.13E-09	3.23E-09	8.82E-10	1.20E-10
2.0E+04	2.26E-08	2.15E-08	1.39E-08	6.23E-09	3.28E-09	8.89E-10	1.21E-10

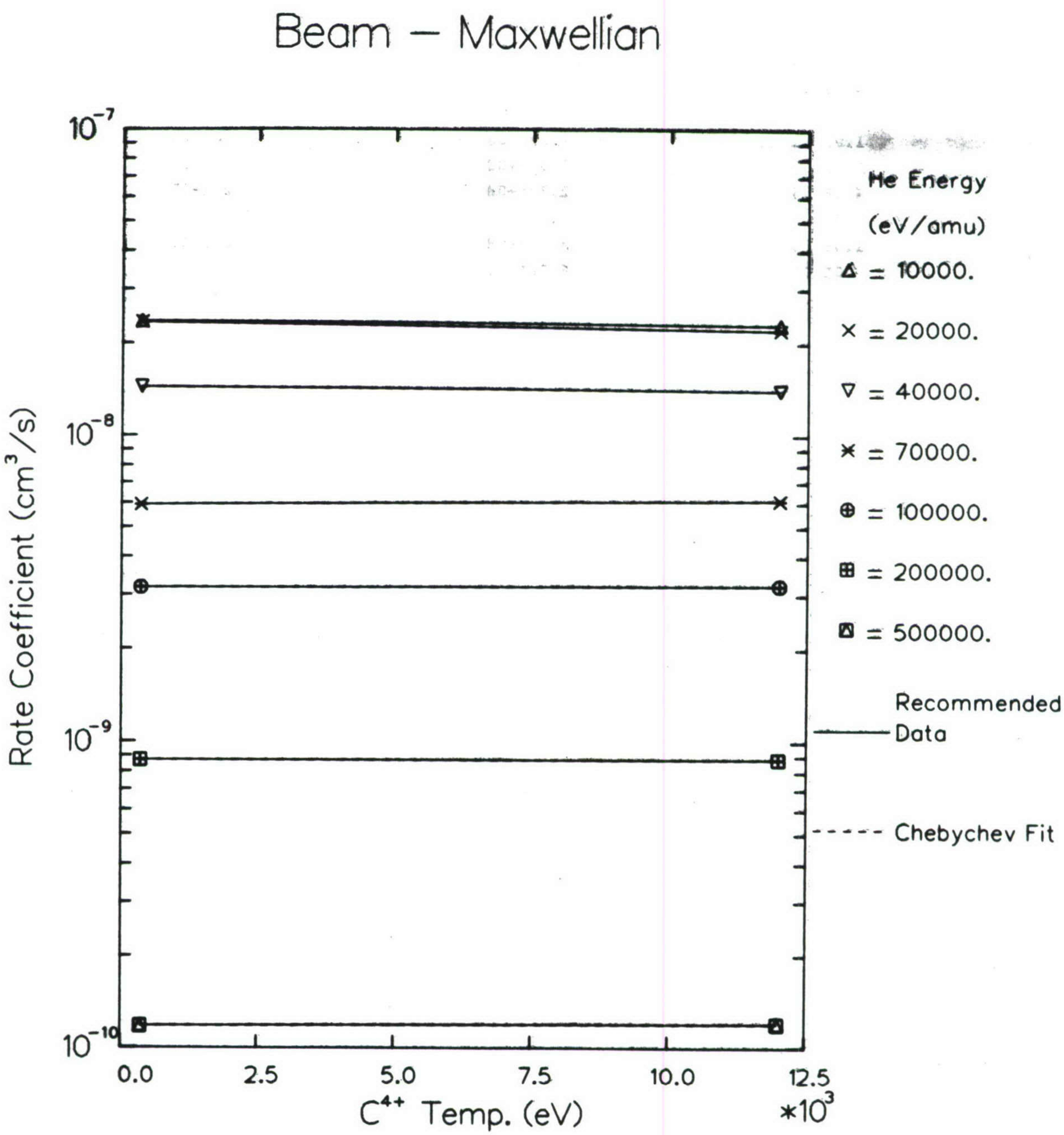
Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 3.6E+02 eV, E_{max} = 2.0E+04 eV

Chebychev Fitting Parameters for Rate Coefficients

He Energy (eV/amu)	C1	C2	C3	C4	C5	C6	C7
10000.	4.657E-08	-4.221E-10	-1.526E-10	-4.753E-11	-1.129E-11	3.107E-13	-6.110E-12
20000.	4.553E-08	-9.031E-10	-3.096E-10	-7.742E-11	-1.808E-11	2.101E-12	1.489E-11
40000.	2.847E-08	-2.365E-10	-8.332E-11	-2.289E-11	-5.494E-12	-2.770E-12	-4.216E-13
70000.	1.203E-08	1.488E-10	4.888E-11	1.141E-11	1.889E-12	-5.862E-13	-1.116E-12
100000.	6.394E-09	4.835E-11	2.187E-11	7.313E-12	2.049E-12	1.366E-12	9.942E-13
200000.	1.751E-09	8.449E-12	3.715E-12	1.187E-12	2.053E-13	-8.272E-14	-4.565E-14
500000.	2.379E-10	1.263E-12	3.718E-13	2.516E-14	-4.344E-14	-3.358E-14	-1.323E-14

See appendix for Chebychev fit details.

$He + C^{4+} \rightarrow C^{2+} + He^{2+}$



Total Electron Capture Cross Sections for
$C^{5+} + He \rightarrow C^{4+} + He^{+}$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
4.0E+02	2.78E+07	1.33E-15
7.0E+02	3.68E+07	1.42E-15
1.0E+03	4.39E+07	1.49E-15
1.7E+03	5.66E+07	1.55E-15
2.0E+03	6.21E+07	1.59E-15
4.0E+03	8.79E+07	1.65E-15
7.0E+03	1.16E+08	1.66E-15
1.0E+04	1.39E+08	1.60E-15
2.0E+04	1.96E+08	1.56E-15
4.0E+04	2.78E+08	1.28E-15
7.0E+04	3.68E+08	8.79E-16
1.0E+05	4.39E+08	6.27E-16
2.0E+05	6.21E+08	2.41E-16
4.0E+05	8.78E+08	3.89E-17
7.0E+05	1.16E+09	3.75E-18
1.0E+06	1.39E+09	8.23E-19
2.0E+06	1.96E+09	4.67E-20
2.2E+06	2.06E+09	3.12E-20

References: E.25, E.26, E.33, T.9, T.40

Accuracy: 50% for $4x10^2 \lesssim E(eV/amu) \lesssim 2x10^3$; 100% for $2x10^3 < E(eV/amu) \leq 4x10^4$; 50% for $4x10^4 < E(eV/amu) \lesssim 4x10^5$; 20% for $E \gtrsim 4x10^5$ eV/amu

Notes: (1) The recommended cross section between $2x10^3$ and $4x10^4$ eV/amu is an interpolation with an estimated accuracy of ~ 100%.
(2) In the region below $E = 2x10^2$ eV/amu, the cross section decreases slowly, but an increase is expected at lower energies due to population of $n \gtrsim 4$ shells of C^{4+}.
(3) There is evidence [E.32] that at $E \simeq 3.3x10^2$ eV/amu the n=3 shell of C^{4+} is predominantly populated. Dominant capture to the n=3 shell is expected to continue at least up to $E \simeq 5x10^4$ eV/amu, and down to $E \simeq 50$ eV/amu.

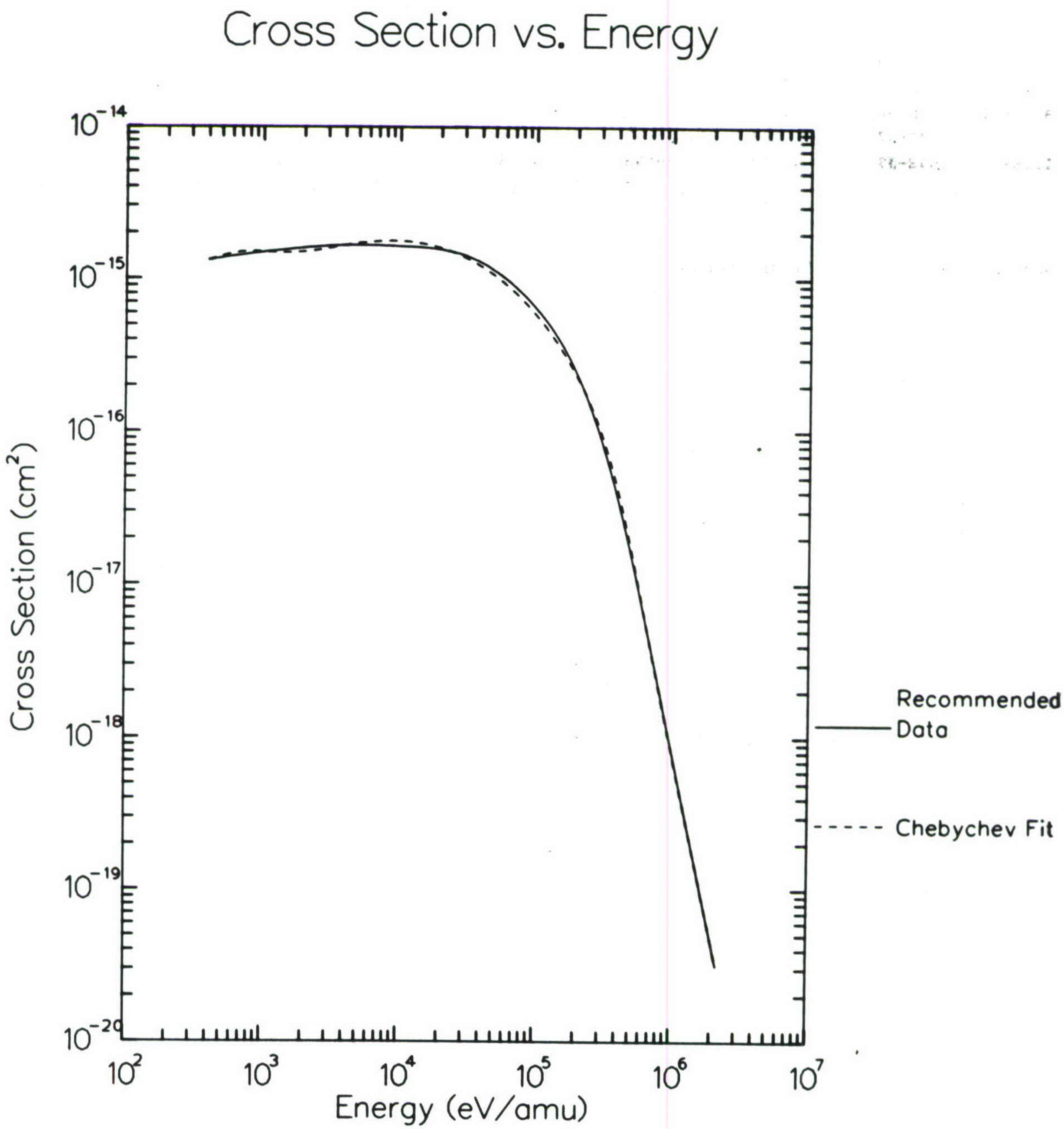
For Chebychev fits of the above cross sections it is necessary to use the following parameters.
E_{min} = 4.0E+02 eV/amu, E_{max} = 2.2E+06 eV/amu

Chebychev Fitting Parameters for Cross Sections

C1	C2	C3	C4	C5	C6	C7	C8	C9
1.768E-15	-8.998E-16	-2.825E-16	2.725E-16	1.406E-16	-8.263E-17	-8.362E-17	5.847E-17	-7.031E-18

The fit represents the above cross sections with an rms deviation of 6.3%.
The maximum deviation is 14.8% at 4.0E+05 eV/amu.
See appendix for Chebychev fit details.

$C^{5+} + He \rightarrow C^{4+} + He^{+}$



Total Electron Capture Rate Coefficients for
$C^{5+} + He \rightarrow C^{4+} + He^{+}$

Maxwellian - Maxwellian Rate Coefficients (cm^3/s)

C^{5+} Temp. (eV)	Equal Temp.	He Temp. (eV) 1.	10.	100.	1000.	5000.	10000.	20000.
5.2E+02	2.37E-08	6.70E-09*	7.11E-09*	1.08E-08*	3.48E-08	8.80E-08	1.27E-07	1.78E-07
8.2E+02	3.31E-08	1.09E-08*	1.12E-08*	1.44E-08	3.68E-08	8.89E-08	1.28E-07	1.78E-07
1.2E+03	4.29E-08	1.54E-08	1.57E-08	1.85E-08	3.93E-08	9.02E-08	1.29E-07	1.79E-07
2.4E+03	6.64E-08	2.66E-08	2.68E-08	2.89E-08	4.63E-08	9.39E-08	1.31E-07	1.80E-07
4.8E+03	9.92E-08	4.29E-08	4.31E-08	4.47E-08	5.84E-08	1.01E-07	1.36E-07	1.83E-07
8.4E+03	1.34E-07	6.12E-08	6.13E-08	6.25E-08	7.36E-08	1.10E-07	1.43E-07	1.88E-07
1.2E+04	1.59E-07	7.58E-08	7.59E-08	7.69E-08	8.63E-08	1.19E-07	1.49E-07	1.92E-07
2.0E+04	2.01E-07	1.01E-07	1.01E-07	1.02E-07	1.09E-07	1.36E-07	1.62E-07	2.01E-07

Accuracy: * - Possible Error Greater Than 10%
** - Possible Error Greater Than 100%

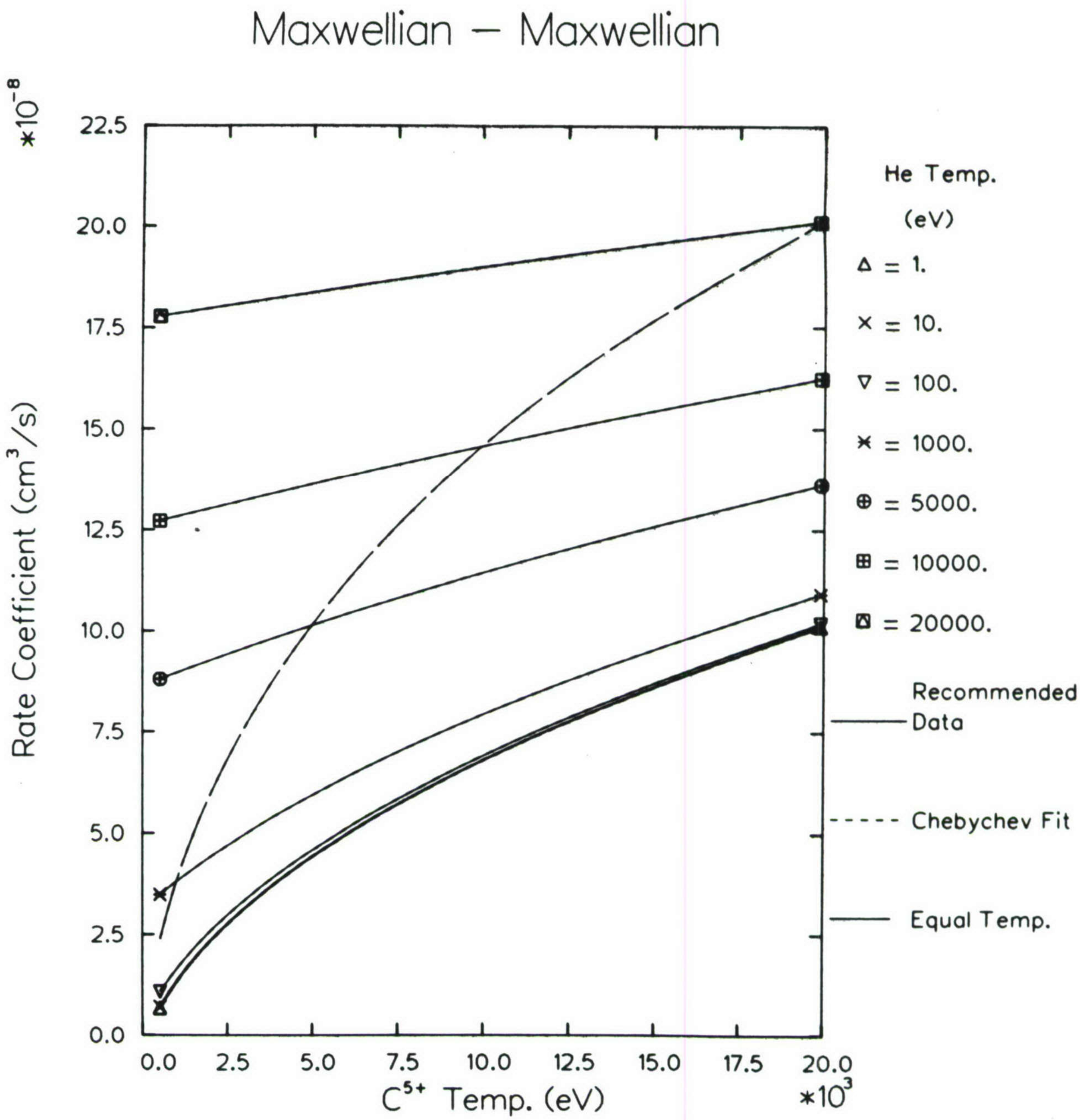
Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 5.2E+02 eV, E_{max} = 2.0E+04 eV

Chebychev Fitting Parameters for Rate Coefficients

He Temp. (eV)	C1	C2	C3	C4	C5	C6	C7
1.	8.646E-08	4.588E-08	1.067E-08	1.418E-09	1.206E-10	-7.942E-12	-2.240E-11
10.	8.690E-08	4.572E-08	1.069E-08	1.417E-09	1.206E-10	-8.727E-12	-2.199E-11
100.	9.101E-08	4.423E-08	1.086E-08	1.434E-09	1.138E-10	-1.314E-11	-1.803E-11
1000.	1.226E-07	3.556E-08	1.071E-08	1.694E-09	6.004E-11	-3.297E-11	-6.555E-12
5000.	2.080E-07	2.241E-08	7.865E-09	1.695E-09	1.919E-10	-1.819E-11	-1.728E-12
10000.	2.771E-07	1.613E-08	5.993E-09	1.438E-09	2.064E-10	9.744E-12	1.603E-11
20000.	3.704E-07	1.067E-08	4.069E-09	1.029E-09	1.736E-10	1.503E-11	-1.507E-12
Equal Temp.	1.916E-07	8.753E-08	1.675E-08	1.097E-09	-2.392E-10	-3.978E-11	8.263E-12

See appendix for Chebychev fit details.

$C^{5+} + He \rightarrow C^{4+} + He^{+}$



Total Electron Capture Rate Coefficients for
$He + C^{5+} \rightarrow C^{4+} + He^{+}$

Beam - Maxwellian Rate Coefficients (cm^3/s)

C^{5+} Temp. (eV)	He Energy (eV/amu) 10000.	20000.	40000.	70000.	100000.	200000.	500000.
5.2E+02	2.23E-07	3.05E-07	3.55E-07	3.23E-07	2.75E-07	1.49E-07	1.65E-08
8.2E+02	2.23E-07	3.05E-07	3.54E-07	3.23E-07	2.75E-07	1.49E-07	1.65E-08
1.2E+03	2.23E-07	3.05E-07	3.54E-07	3.23E-07	2.75E-07	1.49E-07	1.65E-08
2.4E+03	2.25E-07	3.04E-07	3.54E-07	3.22E-07	2.75E-07	1.49E-07	1.65E-08
4.8E+03	2.26E-07	3.04E-07	3.52E-07	3.22E-07	2.74E-07	1.48E-07	1.66E-08
8.4E+03	2.29E-07	3.04E-07	3.50E-07	3.20E-07	2.74E-07	1.48E-07	1.67E-08
1.2E+04	2.32E-07	3.03E-07	3.48E-07	3.20E-07	2.73E-07	1.48E-07	1.68E-08
2.0E+04	2.37E-07	3.03E-07	3.45E-07	3.18E-07	2.72E-07	1.47E-07	1.69E-08

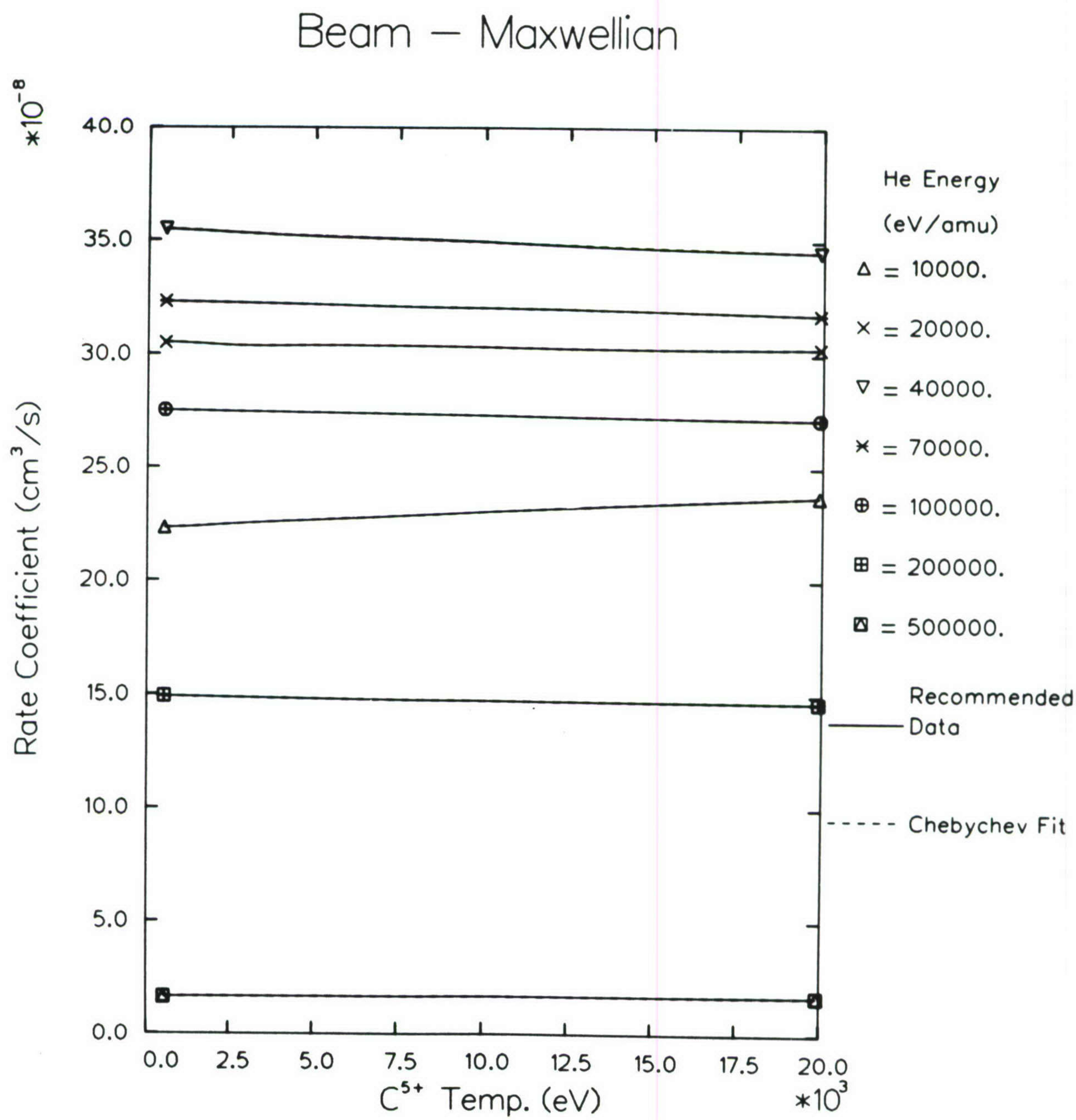
Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 5.2E+02 eV, E_{max} = 2.0E+04 eV

Chebychev Fitting Parameters for Rate Coefficients

He Energy (eV/amu)	C1	C2	C3	C4	C5	C6	C7
10000.	4.552E-07	6.491E-09	2.582E-09	5.319E-10	1.147E-10	1.048E-11	-1.811E-10
20000.	6.076E-07	-1.301E-09	-7.745E-11	4.898E-11	-9.519E-11	2.591E-10	2.449E-10
40000.	7.028E-07	-4.526E-09	-1.528E-09	-2.492E-10	-4.073E-11	-5.237E-11	1.998E-10
70000.	6.428E-07	-2.305E-09	-8.621E-10	-2.382E-10	-5.419E-11	-8.526E-11	-1.755E-10
100000.	5.478E-07	-1.761E-09	-6.304E-10	-1.687E-10	3.197E-12	1.227E-10	1.091E-10
200000.	2.967E-07	-1.123E-09	-2.430E-10	-3.033E-11	-2.449E-11	-2.583E-11	4.905E-12
500000.	3.327E-08	1.971E-10	8.166E-11	2.436E-11	5.735E-12	-8.704E-14	-2.584E-12

See appendix for Chebychev fit details.

$He + C^{5+} \rightarrow C^{4+} + He^{+}$



Total Electron Capture Cross Sections for
$C^{6+} + He \rightarrow C^{5+} + He^{+}$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
2.0E+02	1.96E+07	4.40E-16
4.0E+02	2.78E+07	6.26E-16
7.0E+02	3.68E+07	7.76E-16
1.0E+03	4.39E+07	8.48E-16
1.7E+03	5.66E+07	8.88E-16
2.0E+03	6.21E+07	9.02E-16
4.0E+03	8.79E+07	1.01E-15
7.0E+03	1.16E+08	1.14E-15
1.0E+04	1.39E+08	1.19E-15
2.0E+04	1.96E+08	1.37E-15
2.9E+04	2.37E+08	1.48E-15
4.0E+04	2.78E+08	1.45E-15
7.0E+04	3.68E+08	1.32E-15
1.0E+05	4.39E+08	1.05E-15
2.0E+05	6.21E+08	4.47E-16
4.0E+05	8.78E+08	5.83E-17
7.0E+05	1.16E+09	7.01E-18
1.0E+06	1.39E+09	1.64E-18
2.0E+06	1.96E+09	1.04E-19

References: E.9, E.25, E.26, E.33, E.34, E.35, T.9, T.39, T.41, T.42, T.43, T.44

Accuracy: 40% for $2 \times 10^2 \leq E(eV/amu) < 3 \times 10^5$; 15% for $E \geq 3 \times 10^5$ eV/amu

Notes: (1) Calculations [T.39], [T.44] show that in the region below $E = 2 \times 10^2$ eV/amu the cross section continues to decrease with decreasing energy, at least down to ~ 50 eV/amu.
(2) In the region below ~ 5×10^5 eV/amu (down to probably ~ 50 eV/amu) the calculations [T.39] and experimental measurements [E.35], [E.32] indicate that the n=3 shell of C^{5+} is dominantly populated.
(3) In the region $(1-8) \times 10^3$ eV/amu, the 3p final state is preferentially populated, while outside this energy range capture goes preferentially to the 3d final subshell [T.39], [E.35].

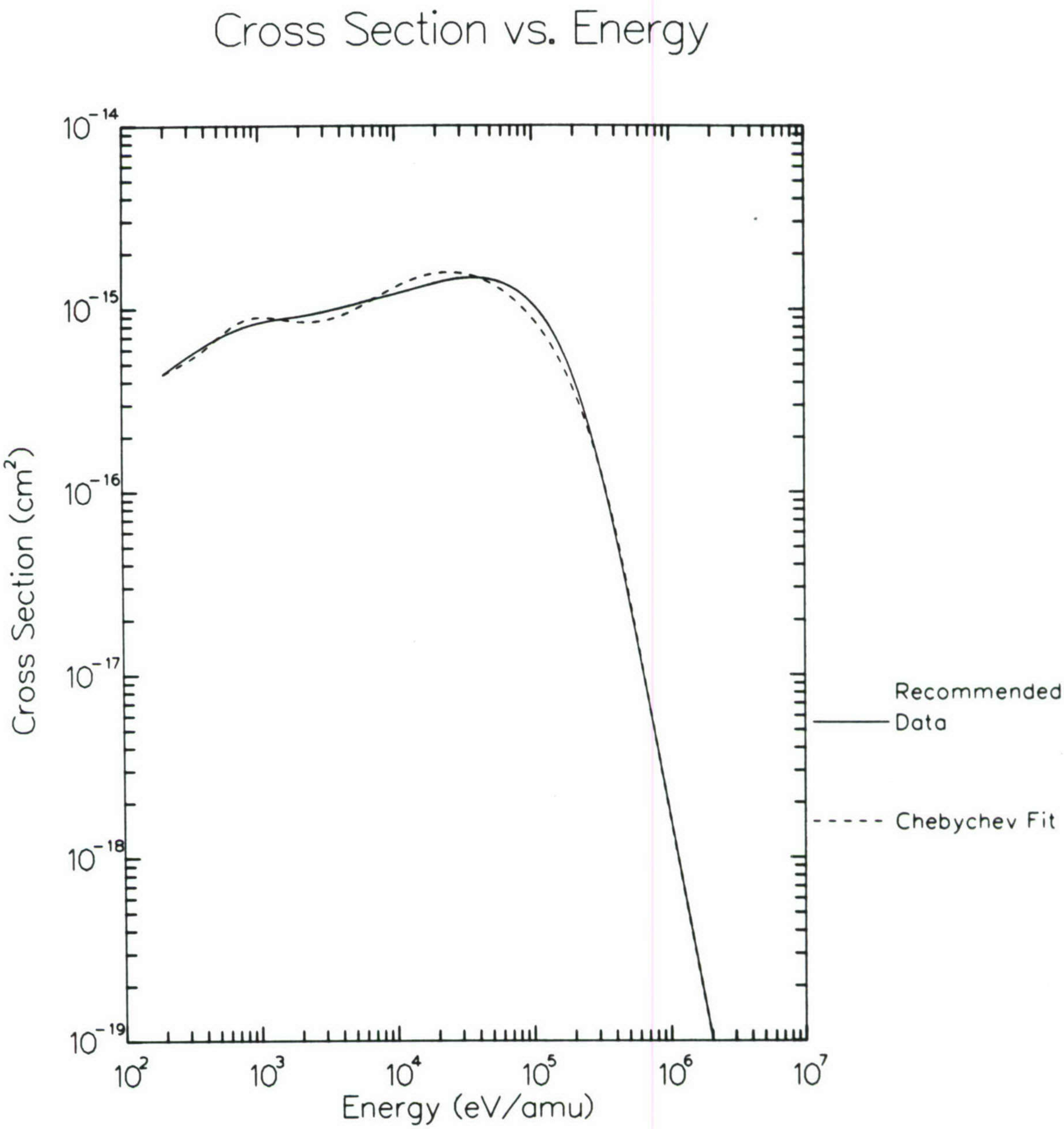
For Chebychev fits of the above cross sections it is necessary to use the following parameters.
E_{min} = 2.0E+02 eV/amu, E_{max} = 2.0E+06 eV/amu

Chebychev Fitting Parameters for Cross Sections

C1	C2	C3	C4	C5	C6	C7	C8	C9
1.169E-15	-3.051E-16	-5.589E-16	8.611E-17	2.187E-16	1.066E-16	-1.093E-16	-1.099E-16	8.743E-17

The fit represents the above cross sections with an rms deviation of 9.2%.
The maximum deviation is 13.8% at 2.0E+04 eV/amu.
See appendix for Chebychev fit details.

$C^{6+} + He \rightarrow C^{5+} + He^{+}$



Total Electron Capture Rate Coefficients for
$C^{6+} + He \rightarrow C^{5+} + He^{+}$

Maxwellian - Maxwellian Rate Coefficients (cm^3/s)

C^{6+} Temp. (eV)	Equal Temp.	He Temp. (eV) 1.	10.	100.	1000.	5000.	10000.	20000.
1.2E+02	2.19E-09	3.58E-10*	4.78E-10*	1.86E-09	1.57E-08	5.04E-08	8.02E-08	1.28E-07
2.4E+02	4.90E-09	9.24E-10	1.06E-09	2.53E-09	1.62E-08	5.07E-08	8.04E-08	1.28E-07
4.8E+02	1.00E-08	2.21E-09	2.36E-09	3.89E-09	1.73E-08	5.12E-08	8.08E-08	1.28E-07
8.4E+02	1.68E-08	4.24E-09	4.39E-09	5.90E-09	1.87E-08	5.20E-08	8.15E-08	1.29E-07
1.2E+03	2.24E-08	6.25E-09	6.40E-09	7.86E-09	2.02E-08	5.28E-08	8.21E-08	1.30E-07
2.4E+03	3.70E-08	1.24E-08	1.26E-08	1.38E-08	2.45E-08	5.54E-08	8.42E-08	1.31E-07
4.8E+03	5.92E-08	2.24E-08	2.25E-08	2.35E-08	3.21E-08	6.04E-08	8.84E-08	1.35E-07
8.4E+03	8.63E-08	3.38E-08	3.39E-08	3.46E-08	4.17E-08	6.76E-08	9.45E-08	1.40E-07
1.2E+04	1.10E-07	4.31E-08	4.32E-08	4.39E-08	5.01E-08	7.45E-08	1.00E-07	1.45E-07
2.0E+04	1.55E-07	6.07E-08	6.07E-08	6.13E-08	6.67E-08	8.86E-08	1.13E-07	1.55E-07

Accuracy: * - Possible Error Greater Than 10%
** - Possible Error Greater Than 100%

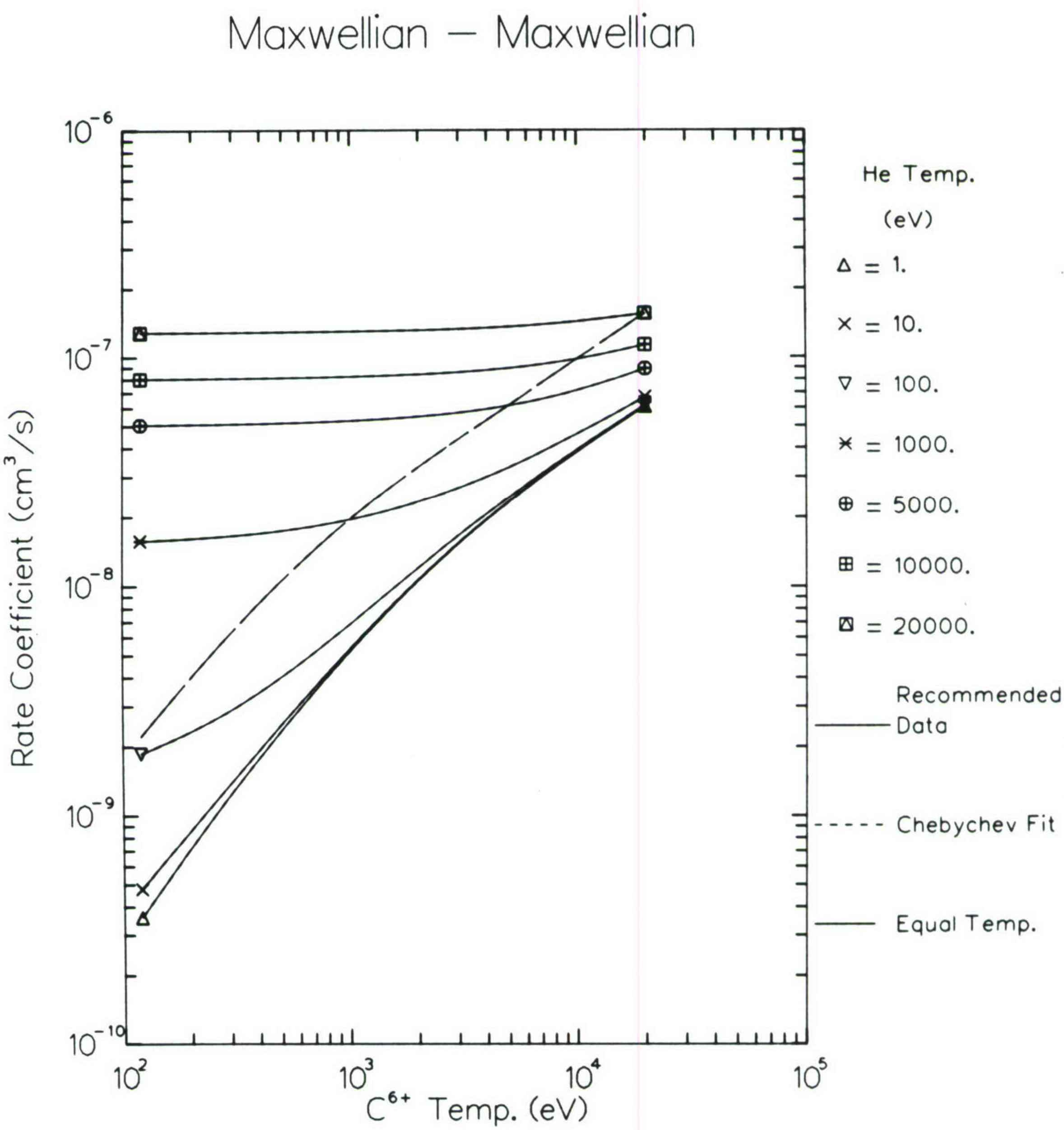
Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.2E+02 eV, E_{max} = 2.0E+04 eV

Chebychev Fitting Parameters for Rate Coefficients

He Temp. (eV)	C1	C2	C3	C4	C5	C6	C7
1.	3.813E-08	2.767E-08	1.110E-08	2.365E-09	2.571E-10	1.096E-10	7.749E-11
10.	3.836E-08	2.763E-08	1.107E-08	2.374E-09	2.627E-10	1.098E-10	7.799E-11
100.	4.063E-08	2.715E-08	1.086E-08	2.438E-09	3.124E-10	1.137E-10	7.702E-11
1000.	6.157E-08	2.259E-08	9.830E-09	2.788E-09	5.600E-10	1.115E-10	3.379E-11
5000.	1.217E-07	1.623E-08	7.955E-09	2.736E-09	6.792E-10	1.162E-10	9.606E-12
10000.	1.779E-07	1.372E-08	6.875E-09	2.469E-09	6.617E-10	1.293E-10	1.719E-11
20000.	2.704E-07	1.133E-08	5.745E-09	2.104E-09	5.764E-10	1.118E-10	1.252E-11
Equal Temp.	1.020E-07	6.926E-08	2.575E-08	6.655E-09	1.768E-09	3.226E-10	-8.899E-11

See appendix for Chebychev fit details.

$C^{6+} + He \rightarrow C^{5+} + He^{+}$



Total Electron Capture Rate Coefficients for
$He + C^{6+} \rightarrow C^{5+} + He^{+}$

Beam - Maxwellian Rate Coefficients (cm^3/s)

C^{6+} Temp. (eV)	He Energy (eV/amu) 10000.	20000.	40000.	70000.	100000.	200000.	500000.
1.2E+02	1.66E-07	2.69E-07	4.03E-07	4.84E-07	4.61E-07	2.77E-07	2.59E-08
2.4E+02	1.66E-07	2.69E-07	4.03E-07	4.84E-07	4.61E-07	2.77E-07	2.59E-08
4.8E+02	1.66E-07	2.69E-07	4.03E-07	4.84E-07	4.61E-07	2.77E-07	2.59E-08
8.4E+02	1.67E-07	2.70E-07	4.03E-07	4.83E-07	4.61E-07	2.76E-07	2.59E-08
1.2E+03	1.67E-07	2.70E-07	4.04E-07	4.82E-07	4.61E-07	2.76E-07	2.59E-08
2.4E+03	1.68E-07	2.70E-07	4.04E-07	4.81E-07	4.60E-07	2.75E-07	2.60E-08
4.8E+03	1.71E-07	2.73E-07	4.03E-07	4.79E-07	4.59E-07	2.74E-07	2.60E-08
8.4E+03	1.75E-07	2.76E-07	4.04E-07	4.76E-07	4.57E-07	2.73E-07	2.61E-08
1.2E+04	1.79E-07	2.78E-07	4.03E-07	4.74E-07	4.55E-07	2.72E-07	2.63E-08
2.0E+04	1.88E-07	2.83E-07	4.04E-07	4.69E-07	4.52E-07	2.70E-07	2.65E-08

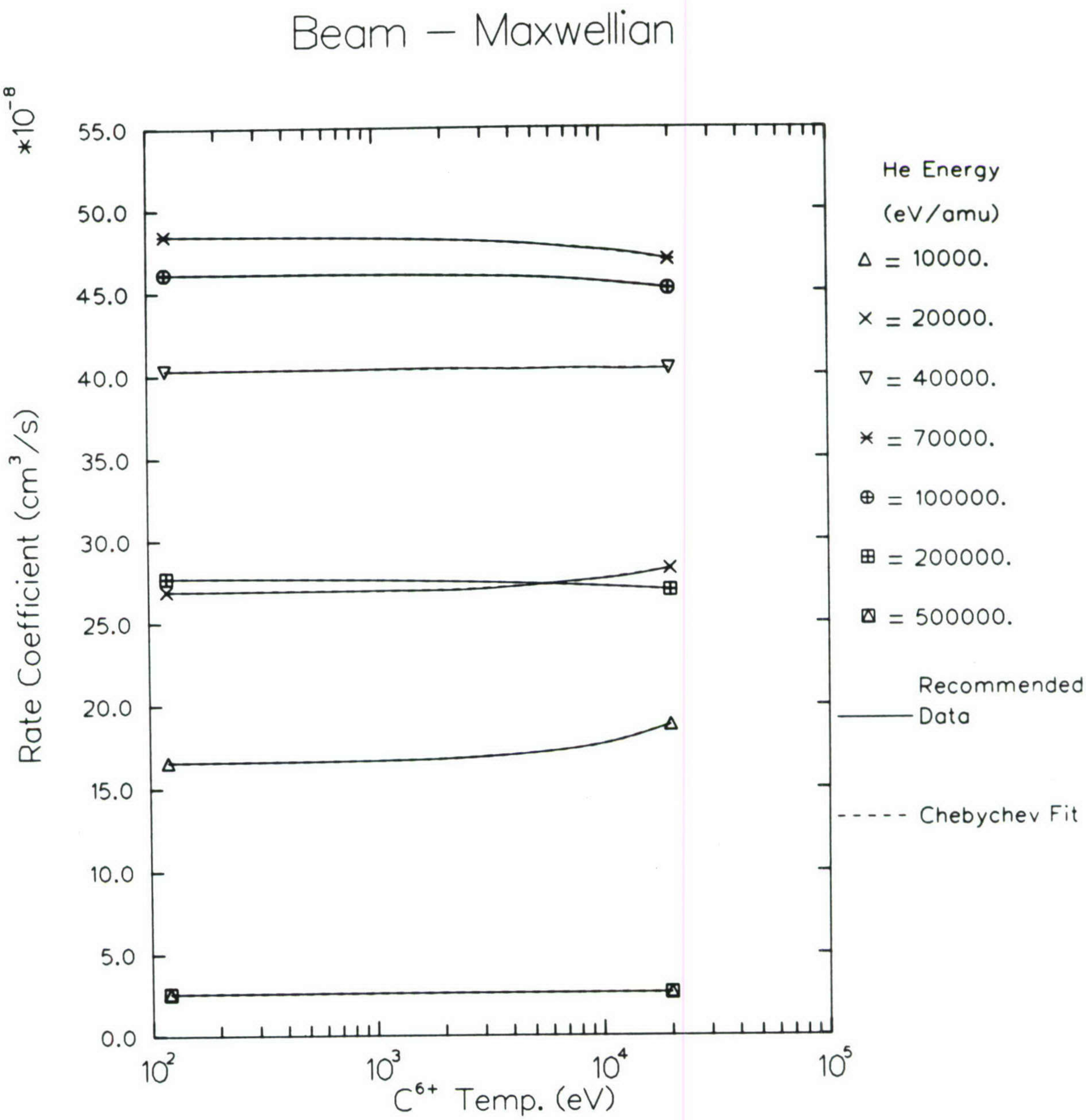
Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.2E+02 eV, E_{max} = 2.0E+04 eV

Chebychev Fitting Parameters for Rate Coefficients

He Energy (eV/amu)	C1	C2	C3	C4	C5	C6	C7
10000.	3.433E-07	9.386E-09	4.674E-09	1.818E-09	5.994E-10	1.992E-10	1.195E-10
20000.	5.456E-07	5.991E-09	2.930E-09	1.012E-09	9.748E-11	-7.839E-11	2.251E-10
40000.	8.069E-07	2.228E-10	-1.115E-10	6.982E-13	7.499E-11	5.024E-11	-6.261E-13
70000.	9.592E-07	-6.744E-09	-2.516E-09	-7.257E-10	-1.416E-10	-2.121E-11	-1.154E-10
100000.	9.170E-07	-3.941E-09	-2.005E-09	-6.658E-10	-1.883E-10	-1.808E-11	1.742E-10
200000.	5.493E-07	-3.341E-09	-1.057E-09	-2.373E-10	-5.074E-11	-3.415E-11	-4.232E-11
500000.	5.209E-08	2.605E-10	1.364E-10	5.358E-11	1.788E-11	5.165E-12	-3.282E-13

See appendix for Chebychev fit details.

$He + C^{6+} \rightarrow C^{5+} + He^{+}$



Total Electron Capture Cross Sections for
$O^+ + He \rightarrow O + He^+$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
1.0E+00	1.39E+06	2.16E-17
2.0E+00	1.96E+06	2.43E-17
4.0E+00	2.78E+06	2.77E-17
7.0E+00	3.68E+06	3.08E-17
1.0E+01	4.39E+06	3.31E-17
2.0E+01	6.21E+06	3.93E-17
4.0E+01	8.79E+06	4.68E-17
7.0E+01	1.16E+07	5.53E-17
1.0E+02	1.39E+07	6.17E-17
2.0E+02	1.96E+07	7.96E-17
4.0E+02	2.78E+07	1.02E-16
7.0E+02	3.68E+07	1.23E-16
1.0E+03	4.39E+07	1.37E-16
1.3E+03	4.91E+07	1.48E-16
2.0E+03	6.21E+07	1.68E-16
4.0E+03	8.79E+07	1.83E-16
7.0E+03	1.16E+08	1.68E-16
1.0E+04	1.39E+08	1.52E-16
2.0E+04	1.96E+08	1.02E-16
4.0E+04	2.78E+08	6.29E-17
7.0E+04	3.68E+08	3.98E-17
1.0E+05	4.39E+08	2.84E-17
2.0E+05	6.21E+08	1.40E-17

References: E.37, E.38, E.39, T.9

Accuracy: 60% for $1 \lesssim E(eV/amu) \lesssim 70$; 100% for $70 \lesssim E(eV/amu) < 2x10^3$; 40% for $E \gtrsim 2x10^3$ eV/amu

Notes: (1) The portion of the cross section curve between 70 and $2x10^3$ eV/amu is a smooth interpolation between two sets of experimental data.
(2) O^+ ions created in a plasma source are known to contain a significant fraction of $^2P^0$ and $^2D^0$ metastables.

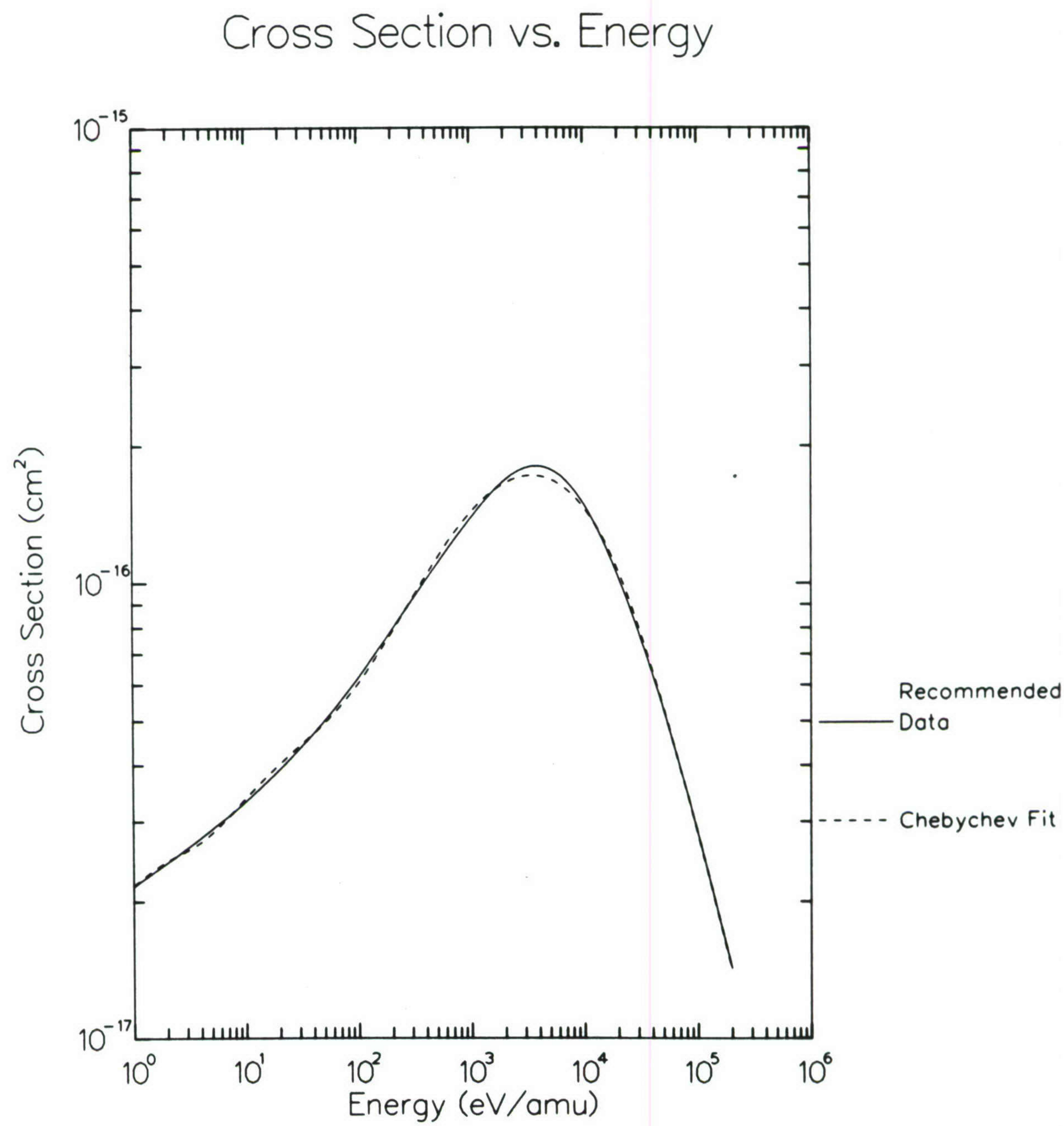
For Chebychev fits of the above cross sections it is necessary to use the following parameters.
E_{min} = 1.0E+00 eV/amu, E_{max} = 2.0E+05 eV/amu

Chebychev Fitting Parameters for Cross Sections

C1	C2	C3	C4	C5	C6	C7	C8	C9
1.243E-16	1.869E-17	-5.255E-17	-3.732E-17	5.562E-18	1.931E-17	7.098E-18	-4.421E-18	-4.531E-18

The fit represents the above cross sections with an rms deviation of 3.1%.
The maximum deviation is 5.2% at 2.0E+04 eV/amu.
See appendix for Chebychev fit details.

$O^+ + He \rightarrow O + He^+$



Total Electron Capture Rate Coefficients for
$O^+ + He \rightarrow O + He^+$

Maxwellian - Maxwellian Rate Coefficients (cm^3/s)

O^+ Temp. (eV)	Equal Temp.	He Temp. (eV) 1.	10.	100.	1000.	5000.	10000.	20000.
1.0E+00	1.70E-11	1.70E-11	7.02E-11	3.77E-10	2.56E-09	8.79E-09	1.29E-08	1.65E-08
4.8E+00	4.86E-11	2.47E-11	7.47E-11	3.80E-10	2.56E-09	8.79E-09	1.29E-08	1.65E-08
8.0E+00	6.91E-11	3.04E-11	7.84E-11	3.83E-10	2.56E-09	8.79E-09	1.29E-08	1.65E-08
1.6E+01	1.13E-10	4.29E-11	8.74E-11	3.88E-10	2.56E-09	8.79E-09	1.29E-08	1.65E-08
3.2E+01	1.87E-10	6.42E-11	1.04E-10	4.00E-10	2.57E-09	8.80E-09	1.29E-08	1.65E-08
6.4E+01	3.16E-10	1.00E-10	1.36E-10	4.24E-10	2.59E-09	8.81E-09	1.29E-08	1.65E-08
1.1E+02	4.92E-10	1.47E-10	1.80E-10	4.58E-10	2.61E-09	8.82E-09	1.29E-08	1.65E-08
1.6E+02	6.59E-10	1.90E-10	2.21E-10	4.92E-10	2.64E-09	8.83E-09	1.29E-08	1.65E-08
3.2E+02	1.18E-09	3.19E-10	3.47E-10	6.04E-10	2.72E-09	8.88E-09	1.30E-08	1.65E-08
6.4E+02	2.12E-09	5.52E-10	5.77E-10	8.20E-10	2.89E-09	8.97E-09	1.30E-08	1.66E-08
1.1E+03	3.37E-09	8.75E-10	8.99E-10	1.13E-09	3.14E-09	9.10E-09	1.31E-08	1.66E-08
1.6E+03	4.50E-09	1.18E-09	1.20E-09	1.42E-09	3.37E-09	9.23E-09	1.32E-08	1.66E-08
3.2E+03	7.57E-09	2.12E-09	2.14E-09	2.34E-09	4.14E-09	9.65E-09	1.34E-08	1.67E-08
6.4E+03	1.16E-08	3.76E-09	3.78E-09	3.95E-09	5.53E-09	1.04E-08	1.38E-08	1.68E-08
1.1E+04	1.48E-08	5.85E-09	5.86E-09	6.00E-09	7.31E-09	1.14E-08	1.43E-08	1.70E-08
1.6E+04	1.65E-08	7.57E-09	7.58E-09	7.70E-09	8.79E-09	1.23E-08	1.48E-08	1.72E-08
2.0E+04	1.74E-08	8.79E-09	8.80E-09	8.90E-09	9.85E-09	1.29E-08	1.52E-08	1.74E-08

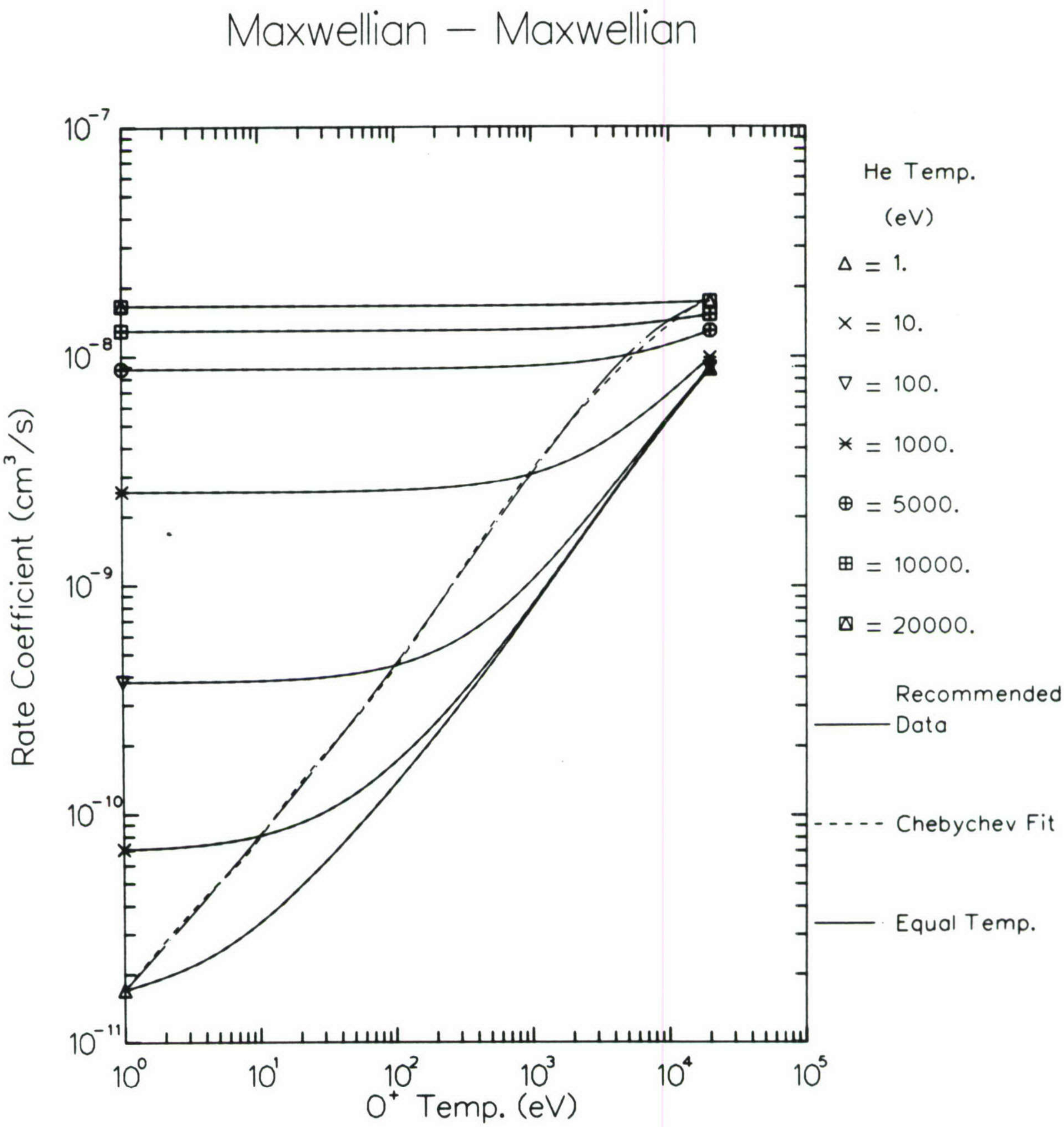
Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

Chebychev Fitting Parameters for Rate Coefficients

He Temp. (eV)	C1	C2	C3	C4	C5	C6	C7
1.	3.783E-09	3.242E-09	2.123E-09	1.081E-09	4.266E-10	1.224E-10	2.110E-11
10.	3.849E-09	3.220E-09	2.123E-09	1.082E-09	4.251E-10	1.220E-10	2.133E-11
100.	4.333E-09	3.123E-09	2.086E-09	1.071E-09	4.165E-10	1.152E-10	1.753E-11
1000.	8.122E-09	2.635E-09	1.790E-09	9.358E-10	3.691E-10	1.023E-10	7.054E-12
5000.	1.926E-08	1.470E-09	1.009E-09	5.370E-10	2.186E-10	6.458E-11	5.218E-12
10000.	2.675E-08	8.058E-10	5.549E-10	2.992E-10	1.248E-10	3.819E-11	5.951E-12
20000.	3.339E-08	2.871E-10	1.988E-10	1.089E-10	4.684E-11	1.524E-11	2.855E-12
Equal Temp.	9.438E-09	7.760E-09	4.349E-09	1.496E-09	1.313E-10	-1.564E-10	-8.172E-11

See appendix for Chebychev fit details.

$O^+ + He \rightarrow O + He^+$



Total Electron Capture Rate Coefficients for
$He + O^+ \rightarrow O + He^+$

Beam - Maxwellian Rate Coefficients (cm^3/s)

O^+ Temp. (eV)	He Energy (eV/amu) 10000.	20000.	40000.	70000.	100000.	200000.	500000.
1.0E+00	2.11E-08	2.00E-08	1.75E-08	1.46E-08	1.25E-08	8.70E-09	4.27E-09
4.8E+00	2.11E-08	2.00E-08	1.75E-08	1.46E-08	1.25E-08	8.70E-09	4.27E-09
8.0E+00	2.11E-08	2.00E-08	1.75E-08	1.46E-08	1.25E-08	8.70E-09	4.27E-09
1.6E+01	2.11E-08	2.00E-08	1.75E-08	1.46E-08	1.25E-08	8.70E-09	4.27E-09
3.2E+01	2.11E-08	2.01E-08	1.75E-08	1.46E-08	1.25E-08	8.70E-09	4.27E-09
6.4E+01	2.11E-08	2.01E-08	1.75E-08	1.46E-08	1.25E-08	8.69E-09	4.27E-09
1.1E+02	2.11E-08	2.01E-08	1.75E-08	1.46E-08	1.25E-08	8.69E-09	4.27E-09
1.6E+02	2.11E-08	2.01E-08	1.75E-08	1.46E-08	1.25E-08	8.69E-09	4.27E-09
3.2E+02	2.11E-08	2.01E-08	1.75E-08	1.46E-08	1.25E-08	8.69E-09	4.27E-09
6.4E+02	2.10E-08	2.01E-08	1.75E-08	1.46E-08	1.25E-08	8.69E-09	4.27E-09
1.1E+03	2.10E-08	2.01E-08	1.75E-08	1.46E-08	1.25E-08	8.69E-09	4.27E-09
1.6E+03	2.09E-08	2.01E-08	1.75E-08	1.46E-08	1.25E-08	8.69E-09	4.27E-09
3.2E+03	2.09E-08	2.01E-08	1.74E-08	1.46E-08	1.25E-08	8.69E-09	4.27E-09
6.4E+03	2.07E-08	2.01E-08	1.74E-08	1.46E-08	1.25E-08	8.67E-09	4.27E-09
1.1E+04	2.05E-08	2.00E-08	1.74E-08	1.45E-08	1.25E-08	8.67E-09	4.27E-09
1.6E+04	2.03E-08	1.99E-08	1.73E-08	1.45E-08	1.24E-08	8.67E-09	4.27E-09
2.0E+04	2.01E-08	1.98E-08	1.73E-08	1.45E-08	1.25E-08	8.66E-09	4.27E-09

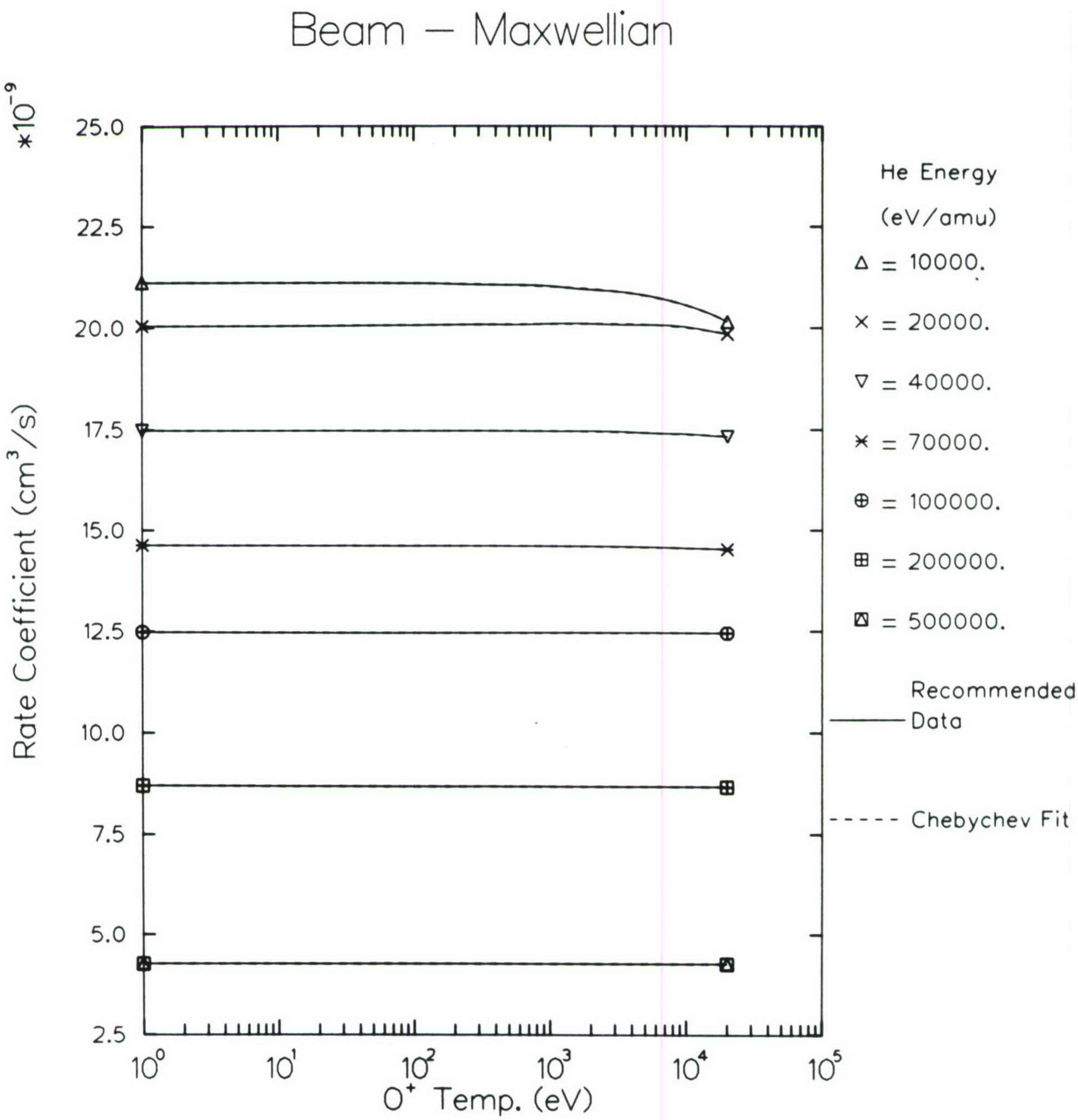
Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

Chebychev Fitting Parameters for Rate Coefficients

He Energy (eV/amu)	C1	C2	C3	C4	C5	C6	C7
10000.	4.182E-08	-3.521E-10	-2.214E-10	-1.132E-10	-4.909E-11	-1.805E-11	-8.414E-12
20000.	4.006E-08	-3.971E-11	-5.699E-11	-4.884E-11	-2.880E-11	-1.237E-11	-6.268E-12
40000.	3.488E-08	-5.487E-11	-3.826E-11	-1.948E-11	-6.961E-12	-1.632E-12	1.582E-12
70000.	2.921E-08	-3.735E-11	-2.538E-11	-1.237E-11	-4.301E-12	-1.217E-12	1.811E-12
100000.	2.494E-08	-6.937E-12	-6.386E-12	-4.052E-12	-1.752E-12	-4.339E-13	-7.405E-14
200000.	1.738E-08	-1.287E-11	-7.068E-12	-2.622E-12	-4.477E-13	3.029E-13	2.737E-13
500000.	8.542E-09	-4.040E-14	-2.919E-13	9.341E-14	3.098E-13	1.916E-13	5.367E-13

See appendix for Chebychev fit details.

$He + O^+ \rightarrow O + He^+$



Total Electron Capture Cross Sections for
$O^{2+} + He \rightarrow O^{+} + He^{+}$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
1.0E+00	1.39E+06	3.26E-16
2.0E+00	1.96E+06	4.63E-16
4.0E+00	2.78E+06	6.43E-16
7.0E+00	3.68E+06	7.84E-16
1.0E+01	4.39E+06	8.86E-16
2.0E+01	6.21E+06	1.08E-15
4.0E+01	8.79E+06	1.26E-15
7.0E+01	1.16E+07	1.32E-15
1.0E+02	1.39E+07	1.30E-15
2.0E+02	1.96E+07	1.17E-15
4.0E+02	2.78E+07	9.63E-16
7.0E+02	3.68E+07	7.46E-16
1.0E+03	4.39E+07	6.46E-16
1.3E+03	4.91E+07	6.25E-16
2.0E+03	6.21E+07	6.45E-16
4.0E+03	8.79E+07	6.92E-16
7.0E+03	1.16E+08	6.13E-16
1.0E+04	1.39E+08	5.06E-16
2.0E+04	1.96E+08	3.22E-16
4.0E+04	2.78E+08	1.89E-16
7.0E+04	3.68E+08	1.22E-16
1.0E+05	4.39E+08	8.56E-17
1.4E+05	5.20E+08	5.81E-17

References: E.22, E.38, E.39, E.40, E.41, T.4, T.9, T.45

Accuracy: 30% for $1 \lesssim E(eV/amu) \lesssim 1x10^3$; 25% for $1x10^3 \lesssim E(eV/amu) \lesssim 1.3x10^5$

Notes: (1) Quantal close-coupling calculations [T.4] show that the cross section continues to decrease with decreasing energy below 1 eV/amu and has a value of about $9.5x10^{-17}$ cm^2 at E = 0.1 eV/amu.
(2) In the region below ~ 10^4 eV/amu capture goes dominantly to the metastable $O^+(2p^3)$ $^2P^0$ and $O^+(2p^3)\,^2D^0$ states, with the $^2P^0$ state being preferentially populated below 10^3 eV/amu, and the $^2D^0$ state above $2x10^3$ eV/amu [T.45].
(3) In the region above ~ 3 eV/amu $O^+(^2D^0)$ is rapidly converted into $O^+(^2P^0)$ in collisions with He^+ (with a cross section greater than 10^{-16} cm^2, which at E = $1.6x10^3$ eV/amu reaches a value of $\approx 10^{-15}$ cm^2) [T.45].

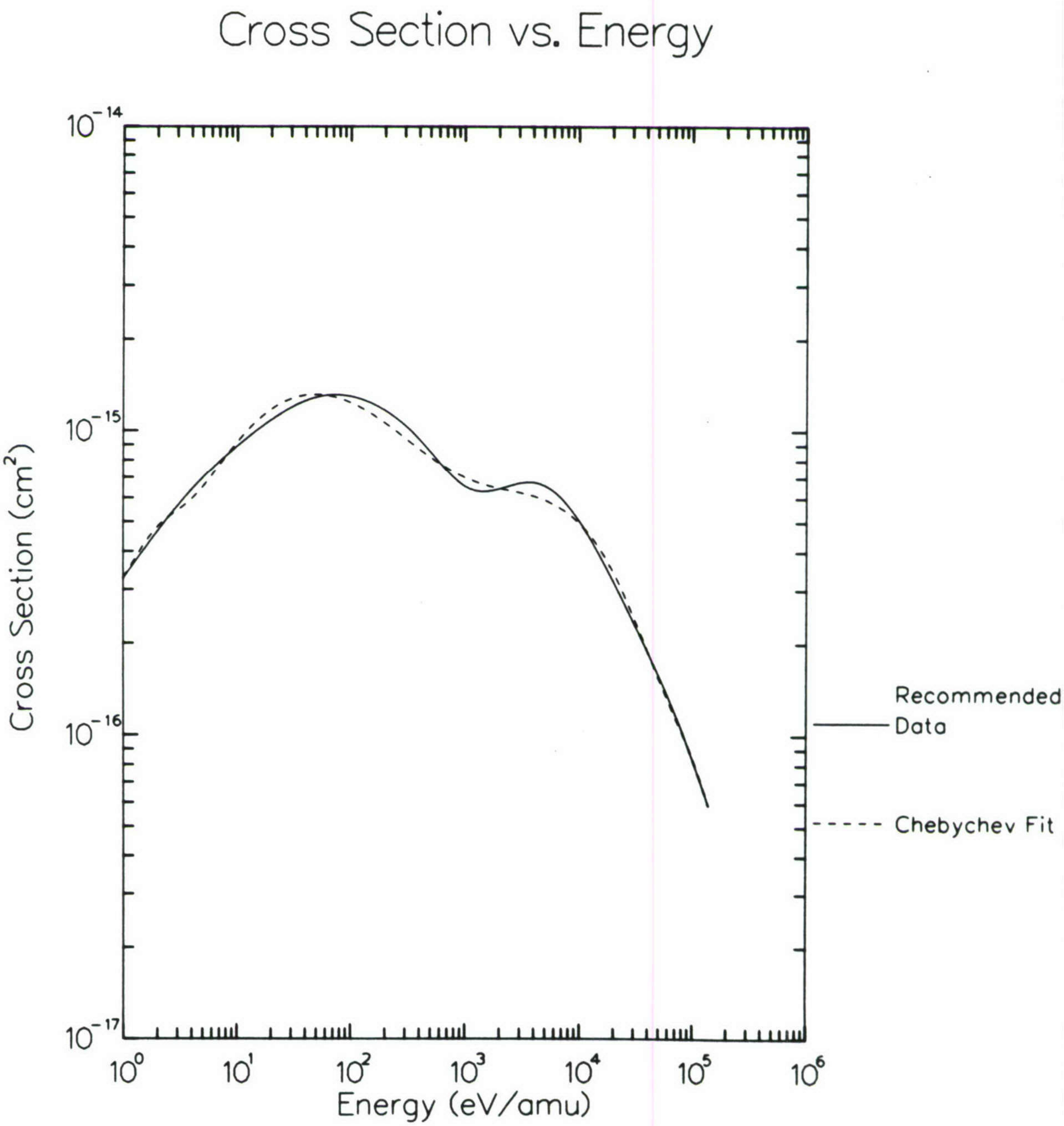
For Chebychev fits of the above cross sections it is necessary to use the following parameters.
E_{min} = 1.0E+00 eV/amu, E_{max} = 1.4E+05 eV/amu

Chebychev Fitting Parameters for Cross Sections

C1	C2	C3	C4	C5	C6	C7	C8	C9
1.140E-15	-2.536E-16	-4.169E-16	1.601E-16	2.354E-17	-8.834E-17	6.642E-17	4.898E-17	-5.242E-17

The fit represents the above cross sections with an rms deviation of 6.3%.
The maximum deviation is 9.1% at 1.0E+03 eV/amu.
See appendix for Chebychev fit details.

$O^{2+} + He \rightarrow O^{+} + He^{+}$



Total Electron Capture Rate Coefficients for
$O^{2+} + He \rightarrow O^{+} + He^{+}$

Maxwellian - Maxwellian Rate Coefficients (cm^3/s)

O^{2+} Temp. (eV)	Equal Temp.	He Temp. (eV) 1.	10.	100.	1000.	5000.	10000.	20000.
1.0E+00	2.09E-10	2.09E-10	1.62E-09	9.34E-09	2.35E-08	3.80E-08	4.98E-08	5.90E-08
1.6E+00	3.37E-10	2.34E-10	1.64E-09	9.35E-09	2.35E-08	3.80E-08	4.98E-08	5.90E-08
3.2E+00	6.73E-10	3.03E-10	1.70E-09	9.37E-09	2.35E-08	3.80E-08	4.98E-08	5.90E-08
6.4E+00	1.30E-09	4.39E-10	1.81E-09	9.42E-09	2.35E-08	3.80E-08	4.98E-08	5.90E-08
1.1E+01	2.12E-09	6.40E-10	1.97E-09	9.49E-09	2.35E-08	3.80E-08	4.98E-08	5.90E-08
1.6E+01	2.87E-09	8.35E-10	2.12E-09	9.55E-09	2.35E-08	3.80E-08	4.98E-08	5.90E-08
3.2E+01	4.96E-09	1.44E-09	2.63E-09	9.77E-09	2.35E-08	3.80E-08	4.98E-08	5.90E-08
6.4E+01	8.10E-09	2.50E-09	3.55E-09	1.02E-08	2.35E-08	3.80E-08	4.98E-08	5.90E-08
1.1E+02	1.13E-08	3.87E-09	4.77E-09	1.08E-08	2.36E-08	3.81E-08	4.98E-08	5.90E-08
1.6E+02	1.36E-08	5.05E-09	5.85E-09	1.13E-08	2.37E-08	3.81E-08	4.98E-08	5.90E-08
3.2E+02	1.82E-08	8.16E-09	8.73E-09	1.30E-08	2.38E-08	3.82E-08	4.99E-08	5.90E-08
6.4E+02	2.23E-08	1.22E-08	1.26E-08	1.54E-08	2.42E-08	3.85E-08	5.00E-08	5.90E-08
1.1E+03	2.52E-08	1.59E-08	1.61E-08	1.79E-08	2.47E-08	3.88E-08	5.02E-08	5.91E-08
1.6E+03	2.75E-08	1.82E-08	1.84E-08	1.96E-08	2.52E-08	3.92E-08	5.04E-08	5.91E-08
3.2E+03	3.47E-08	2.23E-08	2.24E-08	2.29E-08	2.67E-08	4.04E-08	5.10E-08	5.93E-08
6.4E+03	4.59E-08	2.60E-08	2.60E-08	2.64E-08	2.97E-08	4.26E-08	5.22E-08	5.96E-08
1.1E+04	5.49E-08	3.04E-08	3.04E-08	3.07E-08	3.40E-08	4.55E-08	5.36E-08	6.00E-08
1.6E+04	5.90E-08	3.47E-08	3.47E-08	3.50E-08	3.80E-08	4.80E-08	5.49E-08	6.03E-08
2.0E+04	6.06E-08	3.80E-08	3.80E-08	3.83E-08	4.10E-08	4.98E-08	5.58E-08	6.06E-08

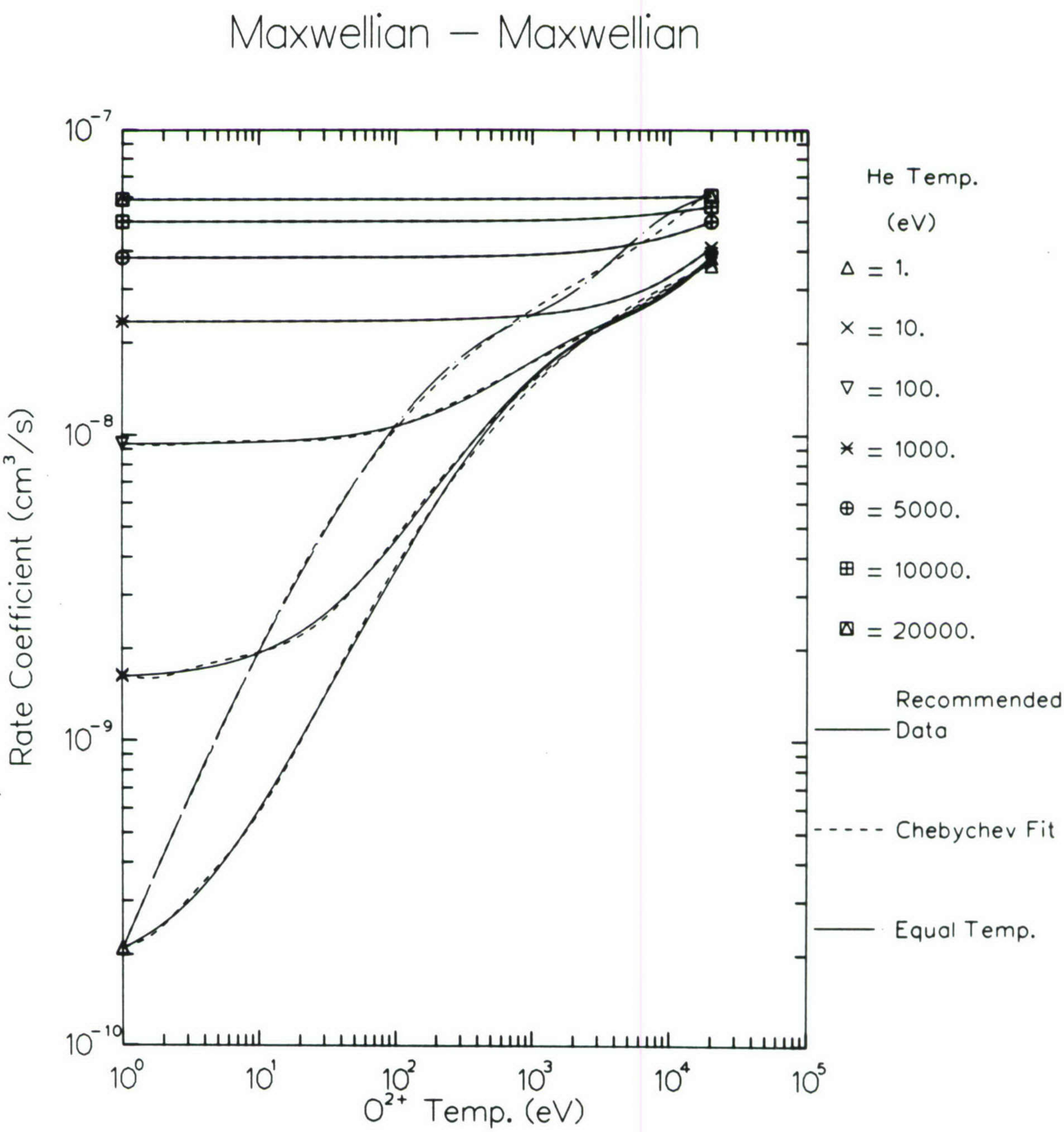
Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

Chebychev Fitting Parameters for Rate Coefficients

He Temp. (eV)	C1	C2	C3	C4	C5	C6	C7
1.	2.429E-08	1.778E-08	6.591E-09	1.648E-10	-8.021E-10	-1.873E-10	3.352E-11
10.	2.574E-08	1.695E-08	6.575E-09	4.694E-10	-4.952E-10	9.053E-11	1.964E-10
100.	3.452E-08	1.252E-08	5.916E-09	1.421E-09	1.423E-10	2.571E-10	2.930E-10
1000.	5.374E-08	6.033E-09	4.178E-09	2.328E-09	1.066E-09	4.061E-10	1.205E-10
5000.	8.072E-08	4.208E-09	2.886E-09	1.545E-09	6.332E-10	1.815E-10	1.786E-11
10000.	1.020E-07	2.162E-09	1.475E-09	7.831E-10	3.164E-10	8.866E-11	8.608E-12
20000.	1.186E-07	5.753E-10	3.927E-10	2.080E-10	8.335E-11	2.253E-11	9.705E-13
Equal Temp.	4.224E-08	2.950E-08	9.701E-09	1.587E-09	1.211E-09	9.958E-10	2.635E-10

See appendix for Chebychev fit details.

$O^{2+} + He \rightarrow O^{+} + He^{+}$



Total Electron Capture Rate Coefficients for
He + O^{2+} -> O^{+} + He^{+}

Beam - Maxwellian Rate Coefficients (cm^3/s)

O^{2+} Temp. (eV)	He Energy (eV/amu) 10000.	20000.	40000.	70000.	100000.	200000.	500000.
1.0E+00	7.03E-08	6.33E-08	5.25E-08	4.48E-08	3.76E-08	2.45E-08	4.96E-09*
1.6E+00	7.03E-08	6.33E-08	5.25E-08	4.48E-08	3.76E-08	2.45E-08	4.96E-09*
3.2E+00	7.03E-08	6.33E-08	5.25E-08	4.48E-08	3.76E-08	2.45E-08	4.96E-09*
6.4E+00	7.03E-08	6.33E-08	5.25E-08	4.48E-08	3.76E-08	2.45E-08	4.96E-09*
1.1E+01	7.03E-08	6.33E-08	5.25E-08	4.48E-08	3.76E-08	2.45E-08	4.96E-09*
1.6E+01	7.03E-08	6.33E-08	5.25E-08	4.48E-08	3.76E-08	2.45E-08	4.96E-09*
3.2E+01	7.03E-08	6.33E-08	5.25E-08	4.48E-08	3.76E-08	2.45E-08	4.97E-09*
6.4E+01	7.03E-08	6.33E-08	5.25E-08	4.48E-08	3.76E-08	2.45E-08	4.97E-09*
1.1E+02	7.04E-08	6.33E-08	5.25E-08	4.48E-08	3.76E-08	2.45E-08	4.98E-09**
1.6E+02	7.04E-08	6.33E-08	5.25E-08	4.48E-08	3.76E-08	2.45E-08	4.98E-09**
3.2E+02	7.03E-08	6.33E-08	5.25E-08	4.48E-08	3.76E-08	2.45E-08	4.99E-09**
6.4E+02	7.04E-08	6.32E-08	5.25E-08	4.48E-08	3.76E-08	2.44E-08	5.00E-09**
1.1E+03	7.03E-08	6.32E-08	5.25E-08	4.47E-08	3.76E-08	2.44E-08	5.01E-09**
1.6E+03	7.01E-08	6.32E-08	5.26E-08	4.47E-08	3.76E-08	2.44E-08	5.02E-09**
3.2E+03	7.00E-08	6.31E-08	5.26E-08	4.46E-08	3.75E-08	2.44E-08	5.05E-09**
6.4E+03	6.95E-08	6.30E-08	5.25E-08	4.45E-08	3.75E-08	2.44E-08	5.09E-09**
1.1E+04	6.87E-08	6.28E-08	5.25E-08	4.43E-08	3.75E-08	2.44E-08	5.13E-09**
1.6E+04	6.79E-08	6.24E-08	5.24E-08	4.43E-08	3.74E-08	2.43E-08	5.17E-09**
2.0E+04	6.73E-08	6.24E-08	5.25E-08	4.42E-08	3.74E-08	2.43E-08	5.19E-09**

Accuracy: * - Possible Error Greater Than 10%
** - Possible Error Greater Than 100%

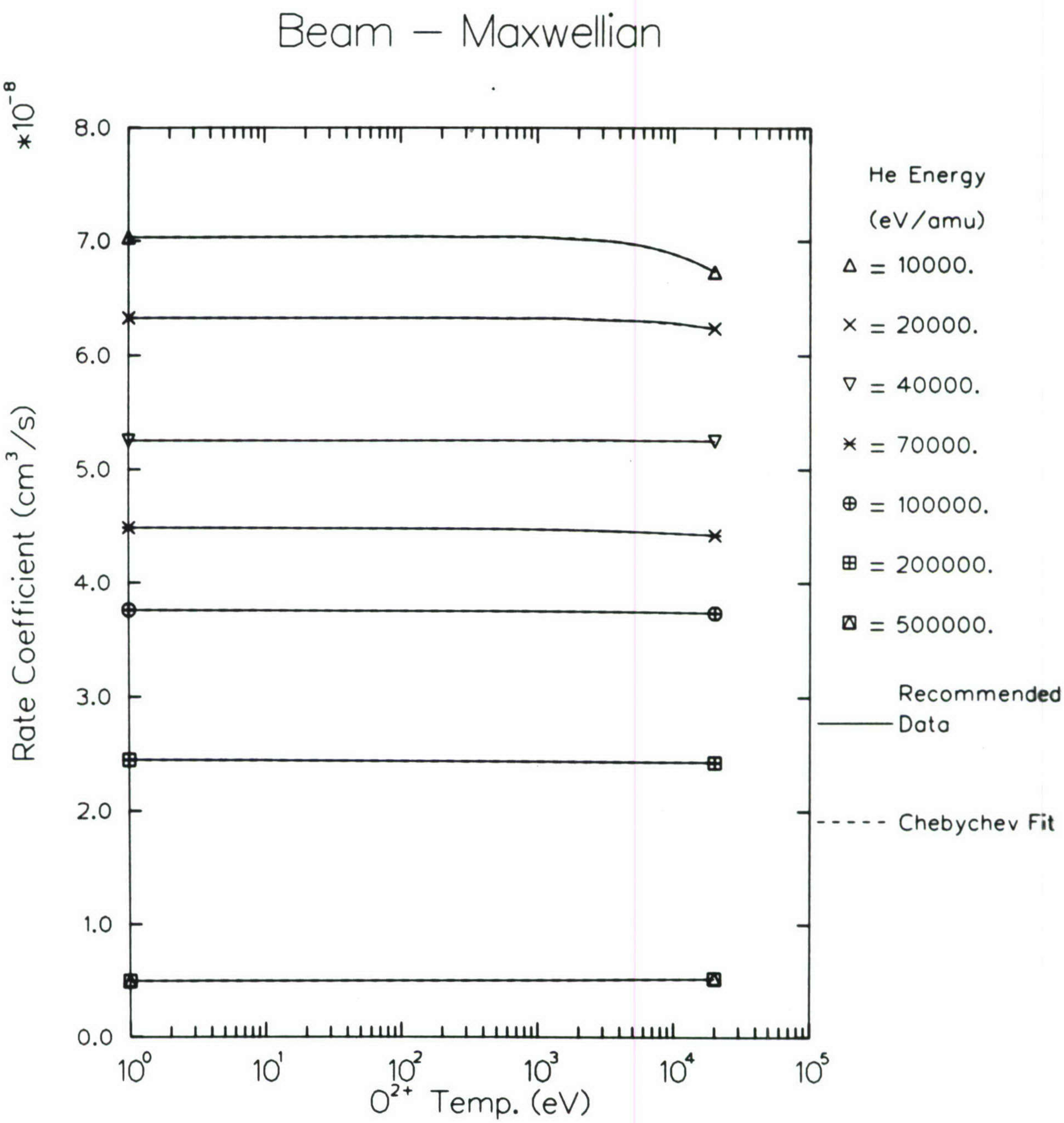
Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

Chebychev Fitting Parameters for Rate Coefficients

He Energy (eV/amu)	C1	C2	C3	C4	C5	C6	C7
10000.	1.396E-07	-9.475E-10	-7.517E-10	-4.644E-10	-2.264E-10	-8.985E-11	-2.798E-11
20000.	1.262E-07	-3.062E-10	-2.230E-10	-1.293E-10	-6.188E-11	-2.678E-11	-1.139E-11
40000.	1.050E-07	-9.250E-13	-2.115E-11	-1.894E-11	-7.213E-12	1.000E-12	4.100E-12
70000.	8.936E-08	-2.524E-10	-1.433E-10	-6.236E-11	-2.036E-11	-3.124E-12	3.374E-12
100000.	7.512E-08	-7.408E-11	-5.231E-11	-2.917E-11	-1.285E-11	-4.333E-12	-1.384E-12
200000.	4.886E-08	-6.945E-11	-3.552E-11	-1.251E-11	-2.343E-12	9.412E-13	7.397E-13
500000.	1.004E-08	9.710E-11	4.919E-11	1.833E-11	5.382E-12	1.304E-12	2.690E-13

See appendix for Chebychev fit details.

$He + O^{2+} \rightarrow O^{+} + He^{+}$



Total Electron Capture Cross Sections for
$O^{3+} + He \rightarrow O^{2+} + He^{+}$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
1.0E+00	1.39E+06	3.40E-16
2.0E+00	1.96E+06	2.58E-16
4.0E+00	2.78E+06	2.13E-16
7.0E+00	3.68E+06	1.85E-16
1.0E+01	4.39E+06	1.71E-16
2.0E+01	6.21E+06	1.56E-16
4.0E+01	8.79E+06	1.47E-16
7.0E+01	1.16E+07	1.44E-16
1.0E+02	1.39E+07	1.50E-16
2.0E+02	1.96E+07	1.59E-16
4.0E+02	2.78E+07	1.80E-16
7.0E+02	3.68E+07	2.06E-16
1.0E+03	4.39E+07	2.26E-16
1.3E+03	4.91E+07	2.47E-16
2.0E+03	6.21E+07	2.86E-16
4.0E+03	8.79E+07	3.58E-16
7.0E+03	1.16E+08	4.10E-16
1.0E+04	1.39E+08	4.36E-16
2.0E+04	1.96E+08	4.53E-16
4.0E+04	2.78E+08	4.06E-16
7.0E+04	3.68E+08	3.06E-16
1.0E+05	4.39E+08	2.11E-16
2.0E+05	6.21E+08	4.72E-17
4.0E+05	8.78E+08	7.18E-18
7.0E+05	1.16E+09	9.99E-19
1.0E+06	1.39E+09	2.76E-19
1.4E+06	1.64E+09	4.33E-20

References: E.22, E.39, E.42, E.43, T.9, T.32, T.46

Accuracy: 100% for $1 \lesssim E(eV/amu) \lesssim 7x10^4$; 25% for $E > 7x10^4$ eV/amu

Notes: (1) The recommended cross-section between 1 and $7x10^4$ eV/amu was constructed on the basis of experimental data from Ref. [E.22] at $E \simeq 1.5x10^3$ eV/amu, and theoretical Landau-Zener calculations in the region $3x10^{-2} \lesssim E(eV/amu) \lesssim 0.8$ [T.32].

(2) In calculations of reaction rates we have extended the cross section down to $E = 10^{-2}$ eV/amu (with $\sigma \simeq 6x10^{-15}$ cm^2 at this energy) by following the slope of the data from [T.32].

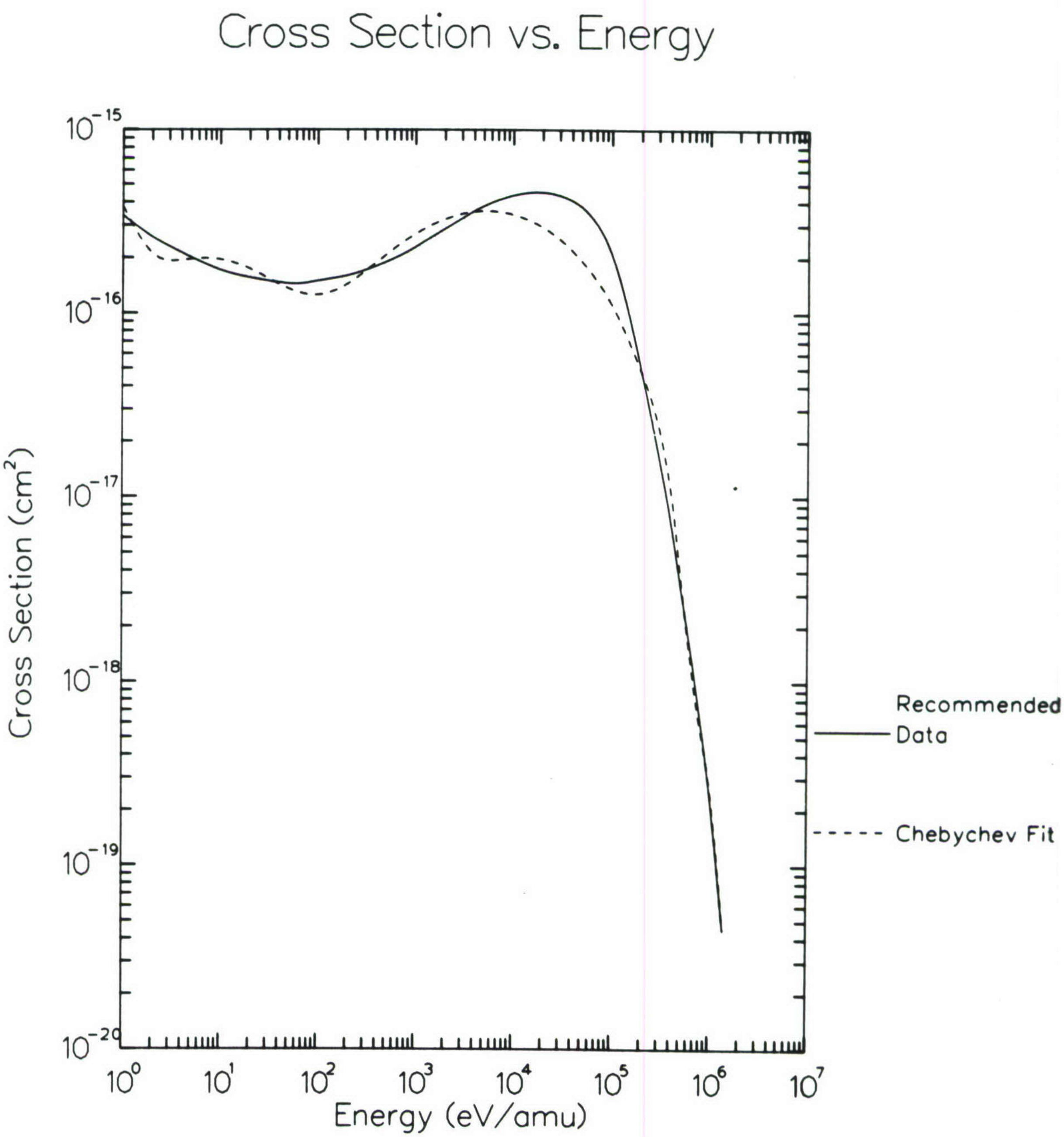
For Chebychev fits of the above cross sections it is necessary to use the following parameters.
E_{min} = 1.0E+00 eV/amu, E_{max} = 1.4E+06 eV/amu

Chebychev Fitting Parameters for Cross Sections

C1	C2	C3	C4	C5	C6	C7	C8	C9
3.461E-16	-1.079E-16	-5.893E-17	-8.508E-17	5.456E-17	4.013E-17	1.211E-17	-3.685E-17	8.950E-18

The fit represents the above cross sections with an rms deviation of 22.6%.
The maximum deviation is 46.5% at 4.0E+05 eV/amu.
See appendix for Chebychev fit details.

$O^{3+} + He \rightarrow O^{2+} + He^{+}$



Total Electron Capture Rate Coefficients for
$O^{3+} + He \rightarrow O^{2+} + He^{+}$

Maxwellian - Maxwellian Rate Coefficients (cm^3/s)

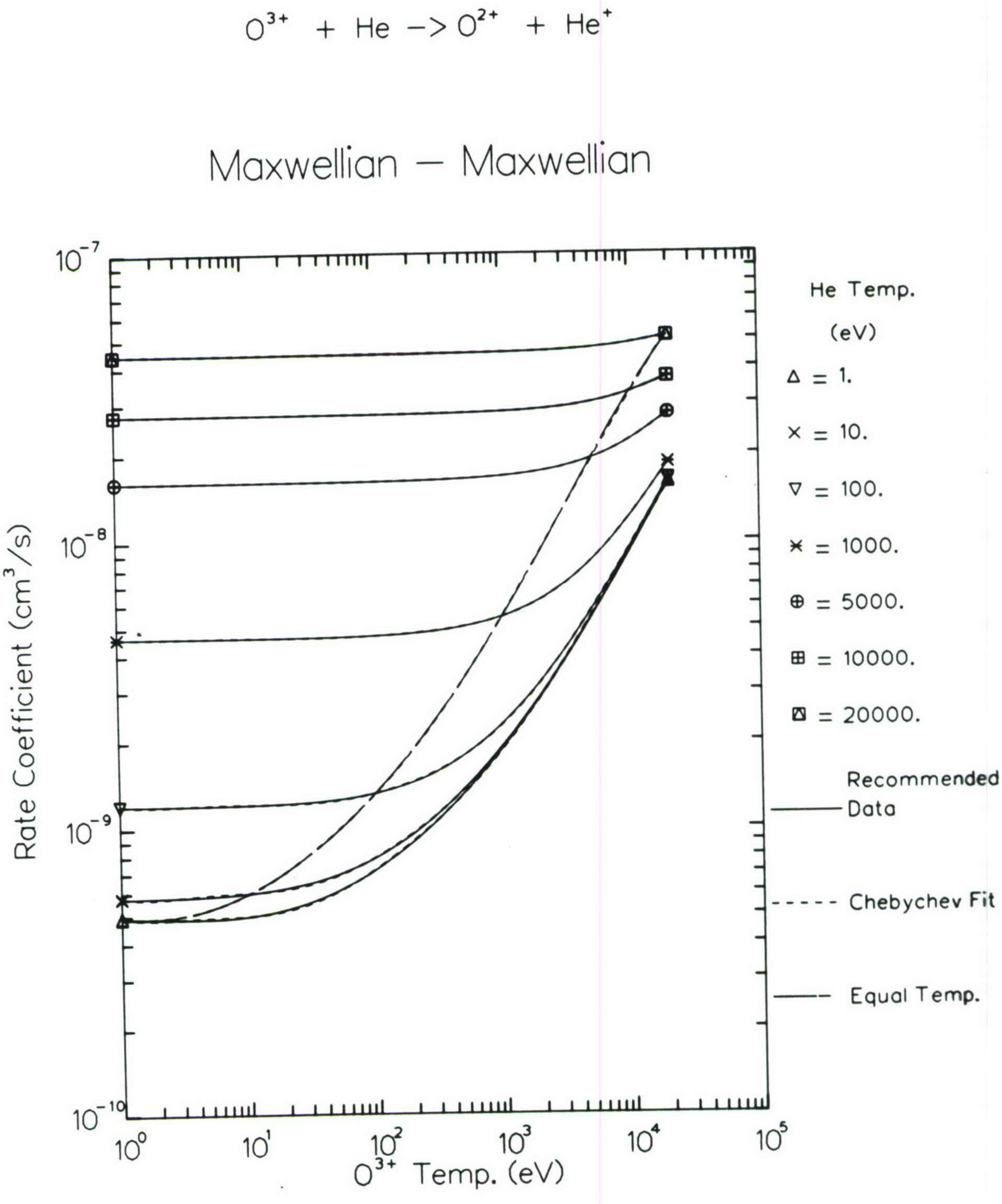
O^{3+} Temp. (eV)	Equal Temp.	He Temp. (eV) 1.	10.	100.	1000.	5000.	10000.	20000.
1.0E+00	4.91E-10	4.91E-10	5.74E-10	1.20E-09	4.62E-09	1.61E-08	2.75E-08	4.45E-08
1.1E+00	4.89E-10	4.90E-10	5.74E-10	1.20E-09	4.62E-09	1.61E-08	2.75E-08	4.45E-08
1.6E+00	4.87E-10	4.89E-10	5.75E-10	1.20E-09	4.62E-09	1.61E-08	2.75E-08	4.45E-08
3.2E+00	5.01E-10	4.87E-10	5.80E-10	1.20E-09	4.62E-09	1.61E-08	2.75E-08	4.45E-08
6.4E+00	5.48E-10	4.89E-10	5.88E-10	1.21E-09	4.62E-09	1.61E-08	2.75E-08	4.45E-08
1.1E+01	6.14E-10	4.99E-10	6.01E-10	1.21E-09	4.63E-09	1.61E-08	2.75E-08	4.45E-08
1.6E+01	6.71E-10	5.13E-10	6.14E-10	1.22E-09	4.63E-09	1.61E-08	2.75E-08	4.45E-08
3.2E+01	8.32E-10	5.60E-10	6.53E-10	1.24E-09	4.64E-09	1.61E-08	2.75E-08	4.45E-08
6.4E+01	1.09E-09	6.43E-10	7.24E-10	1.28E-09	4.67E-09	1.61E-08	2.75E-08	4.45E-08
1.1E+02	1.41E-09	7.49E-10	8.18E-10	1.34E-09	4.71E-09	1.62E-08	2.75E-08	4.45E-08
1.6E+02	1.69E-09	8.40E-10	9.02E-10	1.41E-09	4.75E-09	1.62E-08	2.76E-08	4.45E-08
3.2E+02	2.51E-09	1.09E-09	1.14E-09	1.60E-09	4.88E-09	1.63E-08	2.76E-08	4.46E-08
6.4E+02	3.95E-09	1.51E-09	1.55E-09	1.95E-09	5.14E-09	1.65E-08	2.78E-08	4.47E-08
1.1E+03	5.91E-09	2.04E-09	2.08E-09	2.44E-09	5.53E-09	1.68E-08	2.81E-08	4.48E-08
1.6E+03	7.77E-09	2.52E-09	2.55E-09	2.89E-09	5.91E-09	1.71E-08	2.83E-08	4.50E-08
3.2E+03	1.35E-08	3.95E-09	3.98E-09	4.28E-09	7.16E-09	1.81E-08	2.91E-08	4.56E-08
6.4E+03	2.32E-08	6.54E-09	6.57E-09	6.85E-09	9.55E-09	2.00E-08	3.06E-08	4.67E-08
1.1E+04	3.50E-08	1.01E-08	1.02E-08	1.04E-08	1.29E-08	2.28E-08	3.29E-08	4.83E-08
1.6E+04	4.45E-08	1.35E-08	1.35E-08	1.37E-08	1.61E-08	2.54E-08	3.50E-08	4.98E-08
2.0E+04	5.10E-08	1.61E-08	1.61E-08	1.63E-08	1.86E-08	2.75E-08	3.67E-08	5.10E-08

Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

Chebychev Fitting Parameters for Rate Coefficients

He Temp. (eV)	C1	C2	C3	C4	C5	C6	C7
1.	7.375E-09	5.531E-09	3.618E-09	1.869E-09	8.073E-10	2.833E-10	6.444E-11
10.	7.499E-09	5.493E-09	3.612E-09	1.883E-09	8.074E-10	2.815E-10	6.743E-11
100.	8.428E-09	5.283E-09	3.583E-09	1.923E-09	8.311E-10	2.887E-10	7.288E-11
1000.	1.462E-08	4.775E-09	3.342E-09	1.876E-09	8.493E-10	3.056E-10	8.079E-11
5000.	3.653E-08	3.863E-09	2.722E-09	1.548E-09	7.167E-10	2.682E-10	7.770E-11
10000.	5.848E-08	3.122E-09	2.206E-09	1.262E-09	5.904E-10	2.253E-10	6.837E-11
20000.	9.139E-08	2.207E-09	1.563E-09	8.991E-10	4.252E-10	1.653E-10	5.233E-11
Equal Temp.	2.319E-08	1.908E-08	1.226E-08	6.085E-09	2.333E-09	6.266E-10	9.097E-11

See appendix for Chebychev fit details.



O^{3+} + He -> O^{2+} + He^{+}
Maxwellian — Maxwellian
Rate Coefficient (cm^3/s)
O^{3+} Temp. (eV)
10^{-7}
10^{-8}
10^{-9}
10^{-10}
10^0
10^1
10^2
10^3
10^4
10^5
He Temp.
(eV)
Δ = 1.
× = 10.
▽ = 100.
✱ = 1000.
⊕ = 5000.
⊞ = 10000.
⊠ = 20000.
Recommended Data
Chebychev Fit
Equal Temp.

Total Electron Capture Rate Coefficients for
$He + O^{3+} \rightarrow O^{2+} + He^{+}$

Beam - Maxwellian Rate Coefficients (cm^3/s)

O^{3+} Temp. (eV)	He Energy (eV/amu) 10000.	20000.	40000.	70000.	100000.	200000.	500000.
1.0E+00	6.06E-08	8.90E-08	1.13E-07	1.12E-07	9.27E-08	2.93E-08	3.37E-09
1.1E+00	6.06E-08	8.90E-08	1.13E-07	1.12E-07	9.27E-08	2.93E-08	3.37E-09
1.6E+00	6.06E-08	8.90E-08	1.13E-07	1.12E-07	9.27E-08	2.93E-08	3.37E-09
3.2E+00	6.06E-08	8.90E-08	1.13E-07	1.12E-07	9.27E-08	2.93E-08	3.37E-09
6.4E+00	6.06E-08	8.90E-08	1.13E-07	1.12E-07	9.27E-08	2.93E-08	3.37E-09
1.1E+01	6.06E-08	8.90E-08	1.13E-07	1.12E-07	9.27E-08	2.93E-08	3.37E-09
1.6E+01	6.06E-08	8.90E-08	1.13E-07	1.12E-07	9.27E-08	2.93E-08	3.37E-09
3.2E+01	6.06E-08	8.90E-08	1.13E-07	1.12E-07	9.26E-08	2.93E-08	3.37E-09
6.4E+01	6.06E-08	8.90E-08	1.13E-07	1.12E-07	9.26E-08	2.94E-08	3.37E-09
1.1E+02	6.06E-08	8.90E-08	1.13E-07	1.12E-07	9.26E-08	2.94E-08	3.37E-09
1.6E+02	6.06E-08	8.90E-08	1.13E-07	1.12E-07	9.26E-08	2.94E-08	3.37E-09
3.2E+02	6.06E-08	8.90E-08	1.13E-07	1.12E-07	9.25E-08	2.94E-08	3.37E-09
6.4E+02	6.07E-08	8.89E-08	1.13E-07	1.12E-07	9.25E-08	2.94E-08	3.37E-09
1.1E+03	6.07E-08	8.90E-08	1.12E-07	1.12E-07	9.24E-08	2.95E-08	3.37E-09
1.6E+03	6.07E-08	8.90E-08	1.12E-07	1.12E-07	9.23E-08	2.95E-08	3.37E-09
3.2E+03	6.11E-08	8.88E-08	1.12E-07	1.12E-07	9.20E-08	2.96E-08	3.38E-09
6.4E+03	6.17E-08	8.90E-08	1.12E-07	1.11E-07	9.16E-08	2.98E-08	3.39E-09
1.1E+04	6.26E-08	8.92E-08	1.11E-07	1.10E-07	9.11E-08	3.00E-08	3.40E-09
1.6E+04	6.35E-08	8.92E-08	1.11E-07	1.10E-07	9.05E-08	3.02E-08	3.41E-09
2.0E+04	6.41E-08	8.96E-08	1.11E-07	1.09E-07	9.02E-08	3.03E-08	3.42E-09

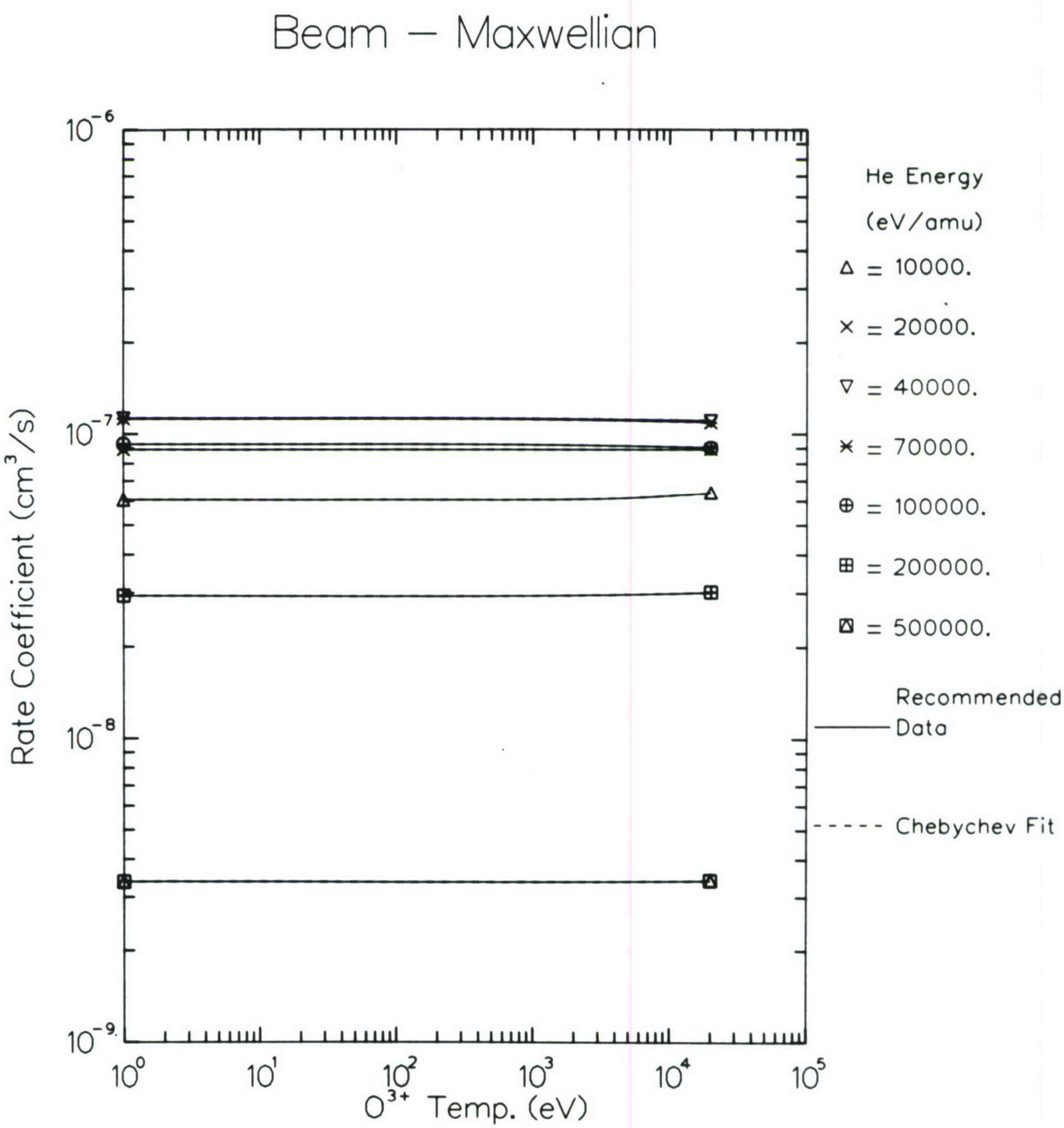
Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

Chebychev Fitting Parameters for Rate Coefficients

He Energy (eV/amu)	C1	C2	C3	C4	C5	C6	C7
10000.	1.224E-07	1.175E-09	8.672E-10	5.216E-10	2.514E-10	9.186E-11	2.068E-11
20000.	1.781E-07	1.071E-10	1.255E-10	1.078E-10	6.855E-11	3.178E-11	1.103E-11
40000.	2.246E-07	-7.890E-10	-4.712E-10	-2.167E-10	-7.385E-11	-1.284E-11	7.059E-12
70000.	2.234E-07	-1.211E-09	-7.351E-10	-3.579E-10	-1.439E-10	-4.530E-11	-5.506E-12
100000.	1.843E-07	-9.196E-10	-5.657E-10	-2.804E-10	-1.174E-10	-4.192E-11	-1.435E-11
200000.	5.910E-08	3.714E-10	2.132E-10	9.778E-11	3.927E-11	1.449E-11	4.672E-12
500000.	6.758E-09	1.639E-11	1.175E-11	7.004E-12	3.577E-12	1.617E-12	7.297E-13

See appendix for Chebychev fit details.

$He + O^{3+} \rightarrow O^{2+} + He^{+}$



Total Electron Capture Cross Sections for
$O^{4+} + He \rightarrow O^{3+} + He^{+}$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
1.0E+00	1.39E+06	2.19E-16
2.0E+00	1.96E+06	1.77E-16
4.0E+00	2.78E+06	1.50E-16
7.0E+00	3.68E+06	1.37E-16
1.0E+01	4.39E+06	1.33E-16
2.0E+01	6.21E+06	1.39E-16
4.0E+01	8.79E+06	1.57E-16
7.0E+01	1.16E+07	1.90E-16
1.0E+02	1.39E+07	2.22E-16
2.0E+02	1.96E+07	3.10E-16
4.0E+02	2.78E+07	4.31E-16
7.0E+02	3.68E+07	5.67E-16
1.0E+03	4.39E+07	6.36E-16
2.0E+03	6.21E+07	7.83E-16
4.0E+03	8.79E+07	8.78E-16
7.0E+03	1.16E+08	8.99E-16
1.0E+04	1.39E+08	8.73E-16
2.0E+04	1.96E+08	7.71E-16
4.0E+04	2.78E+08	6.04E-16
7.0E+04	3.68E+08	4.19E-16
1.0E+05	4.39E+08	3.17E-16
2.0E+05	6.21E+08	1.23E-16
4.0E+05	8.78E+08	2.56E-17
7.0E+05	1.16E+09	2.40E-18
1.0E+06	1.39E+09	5.68E-19
2.0E+06	1.96E+09	3.45E-20

References: E.22, E.39, E.42, E.43, T.9, T.32, T.47

Accuracy: 100% for $1 \lesssim E(eV/amu) < 2x10^3$; 30% for $2x10^3 \lesssim E(eV/amu) \lesssim 1x10^5$; 20% for $E > 1x10^5$ eV/amu

Note: The recommended cross section between 1 and $2x10^3$ eV/amu has been constructed by using the experimental data at $E = 2x10^3$ eV/amu [E.22], and the Landau-Zener calculations in the region $2x10^{-2} \lesssim E(eV/amu) \lesssim 0.8$, considering that the later could overestimate the cross section by at least 50%. This behavior of the cross section was used in calculations of the rate coefficients.

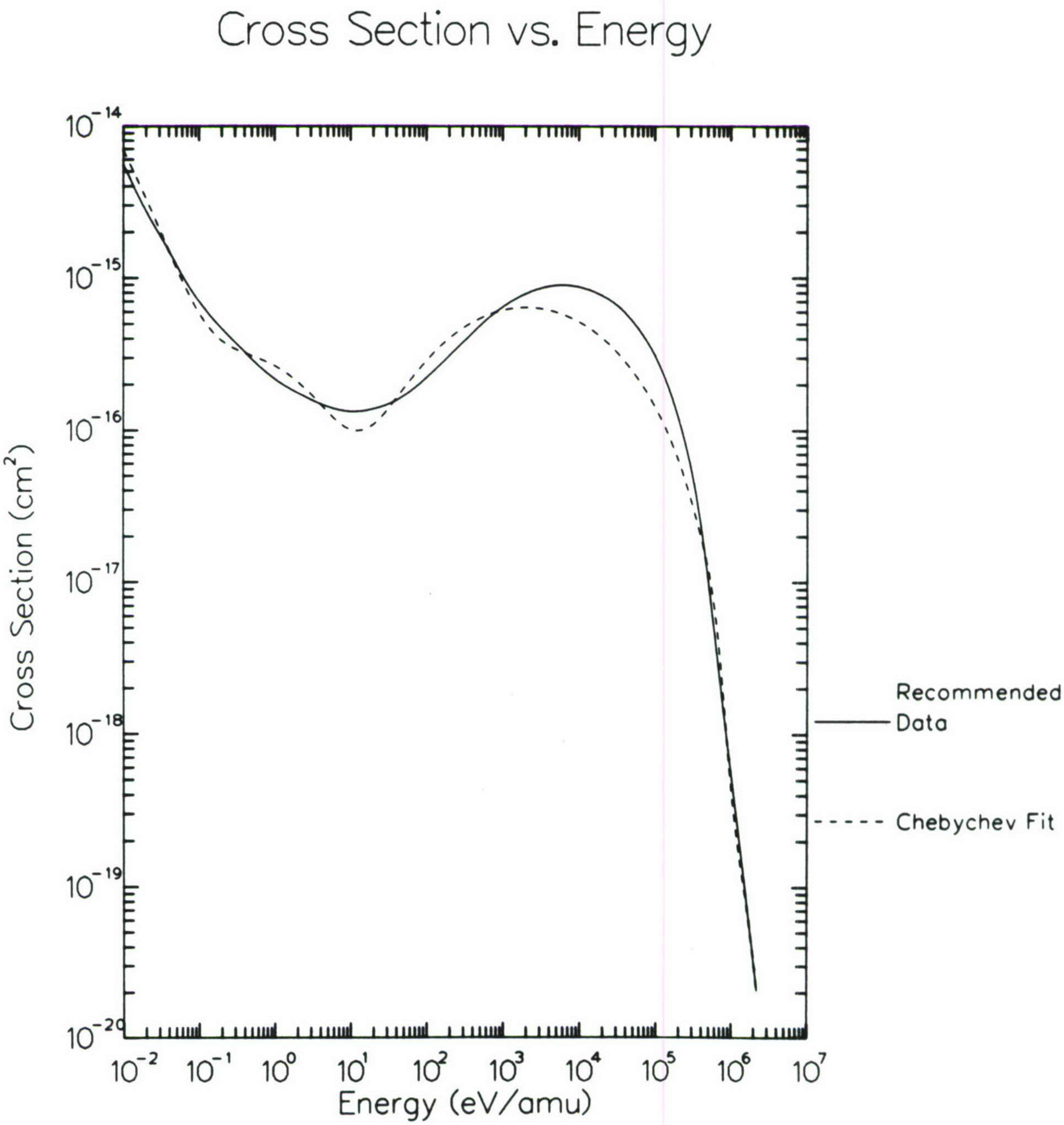
For Chebychev fits of the above cross sections it is necessary to use the following parameters.
E_{min} = 1.0E-02 eV/amu, E_{max} = 2.2E+06 eV/amu

Chebychev Fitting Parameters for Cross Sections

C1	C2	C3	C4	C5	C6	C7	C8	C9
2.067E-15	-1.615E-15	1.211E-15	-1.216E-15	8.243E-16	-4.111E-16	3.513E-16	-2.328E-16	5.573E-17

The fit represents the above cross sections with an rms deviation of 27.8%.
The maximum deviation is 60.6% at 7.0E+05 eV/amu.
See appendix for Chebychev fit details.

$O^{4+} + He \rightarrow O^{3+} + He^{+}$



Total Electron Capture Rate Coefficients for
$O^{4+} + He \rightarrow O^{3+} + He^{+}$

Maxwellian - Maxwellian Rate Coefficients (cm^3/s)

O^{4+} Temp. (eV)	Equal Temp.	He Temp. (eV) 1.	10.	100.	1000.	5000.	10000.	20000.
1.0E+00	3.04E-10	3.04E-10	4.04E-10	1.33E-09	1.10E-08	4.16E-08	6.49E-08	9.27E-08
1.1E+00	3.04E-10	3.04E-10	4.04E-10	1.33E-09	1.10E-08	4.16E-08	6.49E-08	9.27E-08
1.6E+00	3.07E-10	3.04E-10	4.06E-10	1.34E-09	1.10E-08	4.16E-08	6.49E-08	9.27E-08
3.2E+00	3.29E-10	3.05E-10	4.10E-10	1.34E-09	1.10E-08	4.16E-08	6.49E-08	9.27E-08
6.4E+00	3.78E-10	3.13E-10	4.19E-10	1.35E-09	1.10E-08	4.16E-08	6.49E-08	9.27E-08
1.1E+01	4.46E-10	3.27E-10	4.32E-10	1.36E-09	1.10E-08	4.16E-08	6.49E-08	9.27E-08
1.6E+01	5.10E-10	3.41E-10	4.46E-10	1.37E-09	1.11E-08	4.16E-08	6.49E-08	9.27E-08
3.2E+01	7.17E-10	3.89E-10	4.89E-10	1.42E-09	1.11E-08	4.17E-08	6.50E-08	9.27E-08
6.4E+01	1.12E-09	4.78E-10	5.73E-10	1.50E-09	1.12E-08	4.17E-08	6.50E-08	9.28E-08
1.1E+02	1.75E-09	6.04E-10	6.96E-10	1.63E-09	1.13E-08	4.18E-08	6.50E-08	9.28E-08
1.6E+02	2.40E-09	7.27E-10	8.18E-10	1.75E-09	1.14E-08	4.18E-08	6.51E-08	9.28E-08
3.2E+02	4.60E-09	1.13E-09	1.23E-09	2.18E-09	1.18E-08	4.21E-08	6.52E-08	9.29E-08
6.4E+02	8.93E-09	1.98E-09	2.08E-09	3.06E-09	1.26E-08	4.25E-08	6.55E-08	9.31E-08
1.1E+03	1.50E-08	3.29E-09	3.39E-09	4.38E-09	1.38E-08	4.32E-08	6.60E-08	9.33E-08
1.6E+03	2.04E-08	4.61E-09	4.71E-09	5.69E-09	1.50E-08	4.39E-08	6.64E-08	9.36E-08
3.2E+03	3.54E-08	8.94E-09	9.04E-09	9.98E-09	1.87E-08	4.61E-08	6.78E-08	9.44E-08
6.4E+03	5.68E-08	1.69E-08	1.70E-08	1.78E-08	2.54E-08	5.02E-08	7.06E-08	9.59E-08
1.1E+04	7.81E-08	2.70E-08	2.70E-08	2.77E-08	3.41E-08	5.59E-08	7.45E-08	9.82E-08
1.6E+04	9.27E-08	3.54E-08	3.55E-08	3.61E-08	4.16E-08	6.10E-08	7.81E-08	1.00E-07
2.0E+04	1.02E-07	4.16E-08	4.17E-08	4.22E-08	4.72E-08	6.49E-08	8.09E-08	1.02E-07

Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

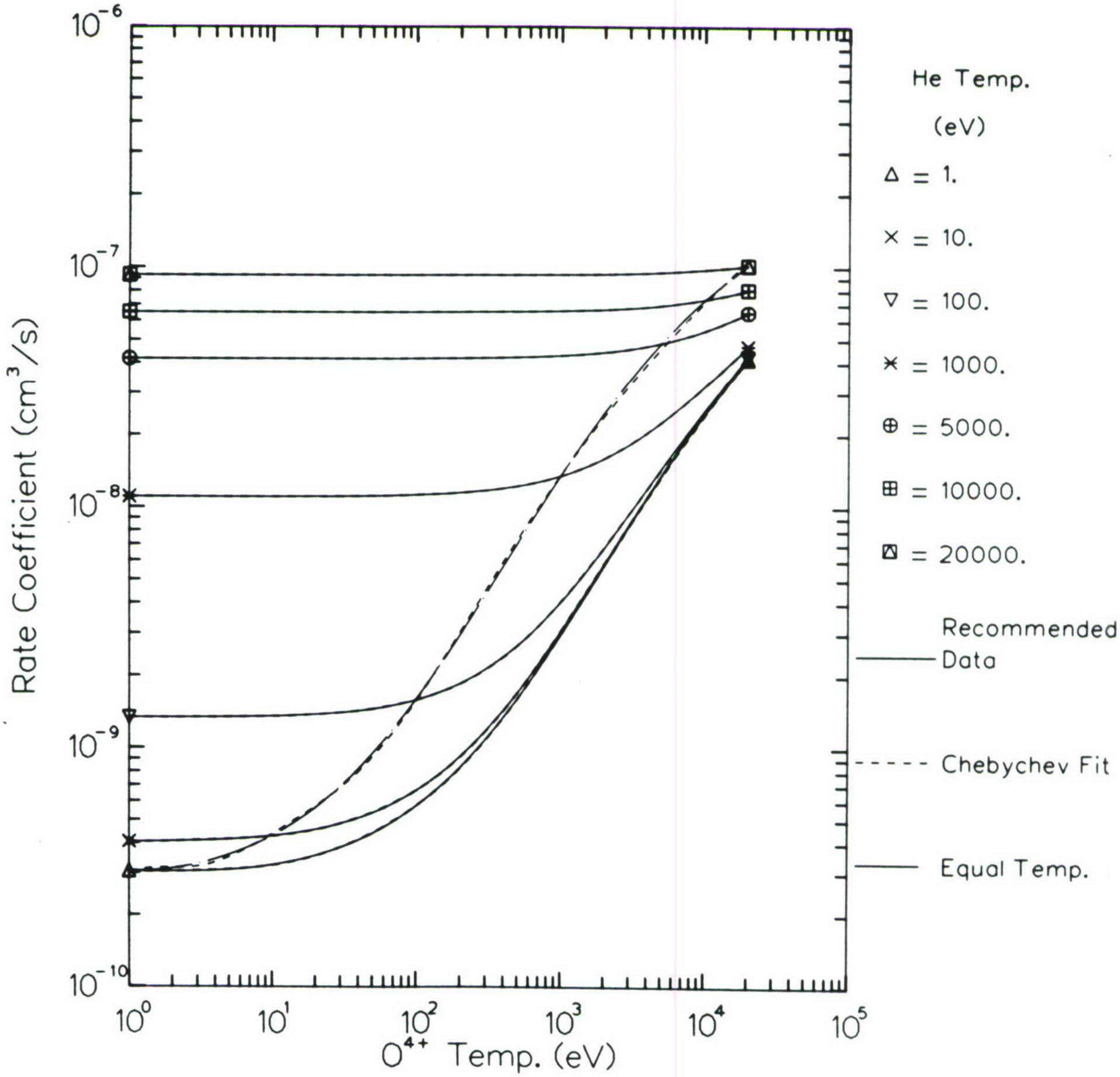
Chebychev Fitting Parameters for Rate Coefficients

He Temp. (eV)	C1	C2	C3	C4	C5	C6	C7
1.	1.745E-08	1.484E-08	1.020E-08	5.479E-09	2.260E-09	6.627E-10	1.079E-10
10.	1.763E-08	1.483E-08	1.019E-08	5.473E-09	2.252E-09	6.607E-10	1.091E-10
100.	1.936E-08	1.470E-08	1.006E-08	5.362E-09	2.184E-09	6.337E-10	1.027E-10
1000.	3.677E-08	1.293E-08	8.804E-09	4.663E-09	1.893E-09	5.514E-10	8.634E-11
5000.	9.242E-08	8.114E-09	5.627E-09	3.096E-09	1.350E-09	4.520E-10	1.014E-10
10000.	1.360E-07	5.473E-09	3.829E-09	2.145E-09	9.672E-10	3.454E-10	9.084E-11
20000.	1.890E-07	3.141E-09	2.213E-09	1.258E-09	5.832E-10	2.189E-10	6.451E-11
Equal Temp.	5.010E-08	4.212E-08	2.579E-08	1.096E-08	2.810E-09	1.832E-10	-9.119E-11

See appendix for Chebychev fit details.

$O^{4+} + He \rightarrow O^{3+} + He^{+}$

Maxwellian – Maxwellian



Total Electron Capture Rate Coefficients for
He + O^{4+} -> O^{3+} + He^{+}

Beam - Maxwellian Rate Coefficients (cm^3/s)

O^{4+} Temp. (eV)	He Energy (eV/amu) 10000.	20000.	40000.	70000.	100000.	200000.	500000.
1.0E+00	1.21E-07	1.51E-07	1.68E-07	1.54E-07	1.39E-07	7.64E-08	1.10E-08
1.1E+00	1.21E-07	1.51E-07	1.68E-07	1.54E-07	1.39E-07	7.64E-08	1.10E-08
1.6E+00	1.21E-07	1.51E-07	1.68E-07	1.54E-07	1.39E-07	7.64E-08	1.10E-08
3.2E+00	1.21E-07	1.51E-07	1.68E-07	1.54E-07	1.39E-07	7.64E-08	1.10E-08
6.4E+00	1.21E-07	1.51E-07	1.68E-07	1.54E-07	1.39E-07	7.64E-08	1.10E-08
1.1E+01	1.21E-07	1.51E-07	1.68E-07	1.54E-07	1.39E-07	7.64E-08	1.10E-08
1.6E+01	1.21E-07	1.51E-07	1.68E-07	1.54E-07	1.39E-07	7.64E-08	1.10E-08
3.2E+01	1.21E-07	1.51E-07	1.68E-07	1.54E-07	1.39E-07	7.64E-08	1.10E-08
6.4E+01	1.21E-07	1.51E-07	1.68E-07	1.54E-07	1.39E-07	7.64E-08	1.10E-08
1.1E+02	1.21E-07	1.51E-07	1.68E-07	1.54E-07	1.39E-07	7.64E-08	1.10E-08
1.6E+02	1.21E-07	1.51E-07	1.68E-07	1.54E-07	1.39E-07	7.64E-08	1.10E-08
3.2E+02	1.21E-07	1.51E-07	1.68E-07	1.54E-07	1.39E-07	7.64E-08	1.10E-08
6.4E+02	1.21E-07	1.51E-07	1.68E-07	1.54E-07	1.39E-07	7.64E-08	1.10E-08
1.1E+03	1.21E-07	1.51E-07	1.67E-07	1.54E-07	1.39E-07	7.63E-08	1.10E-08
1.6E+03	1.21E-07	1.51E-07	1.67E-07	1.54E-07	1.39E-07	7.63E-08	1.10E-08
3.2E+03	1.22E-07	1.51E-07	1.67E-07	1.54E-07	1.38E-07	7.63E-08	1.10E-08
6.4E+03	1.22E-07	1.51E-07	1.66E-07	1.54E-07	1.38E-07	7.62E-08	1.11E-08
1.1E+04	1.22E-07	1.51E-07	1.66E-07	1.54E-07	1.38E-07	7.62E-08	1.11E-08
1.6E+04	1.23E-07	1.50E-07	1.65E-07	1.54E-07	1.37E-07	7.61E-08	1.12E-08
2.0E+04	1.23E-07	1.51E-07	1.65E-07	1.53E-07	1.37E-07	7.61E-08	1.12E-08

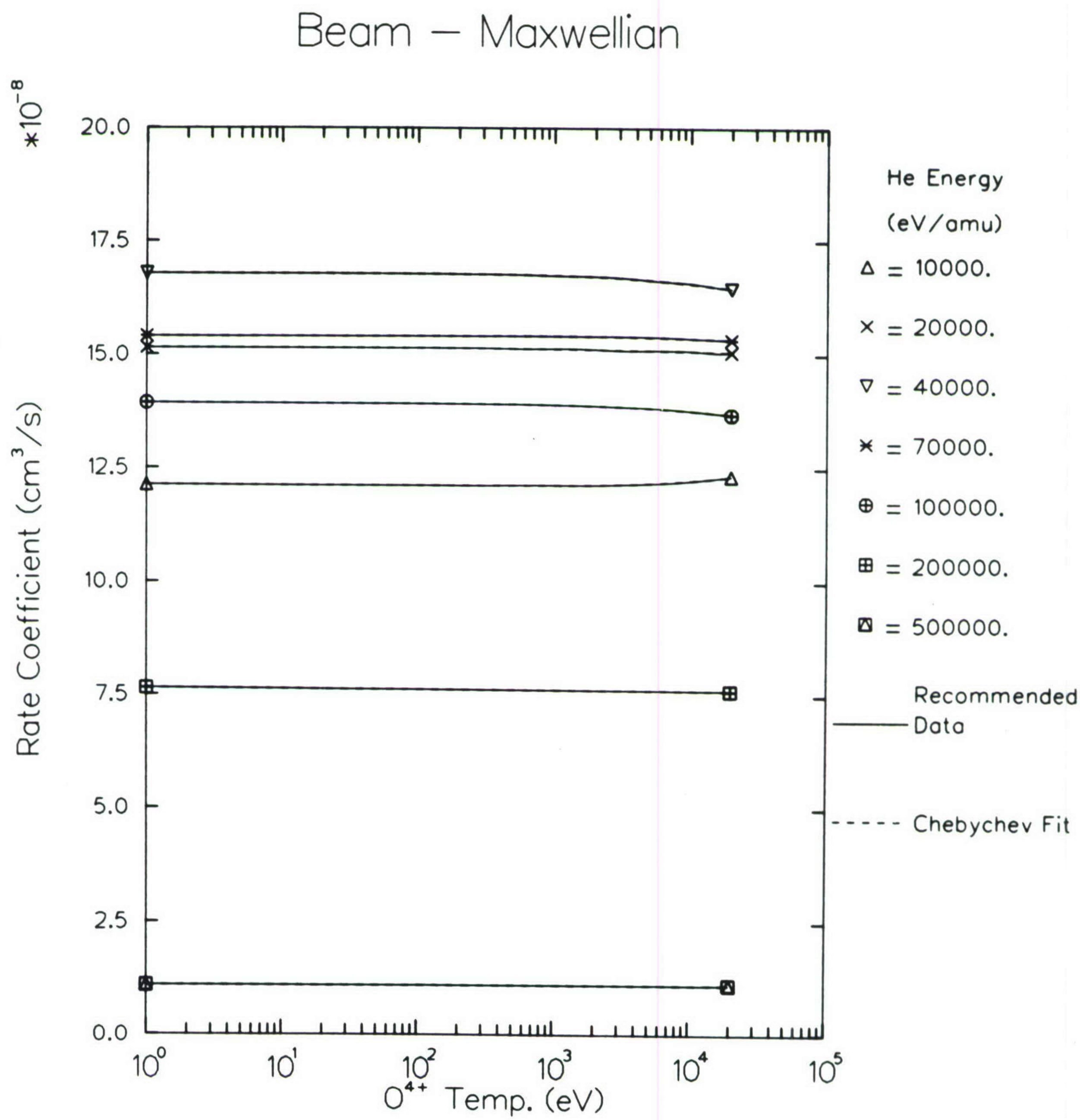
Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

Chebychev Fitting Parameters for Rate Coefficients

He Energy (eV/amu)	C1	C2	C3	C4	C5	C6	C7
10000.	2.433E-07	6.778E-10	4.987E-10	3.115E-10	1.557E-10	5.372E-11	6.117E-12
20000.	3.024E-07	-3.937E-10	-2.110E-10	-7.293E-11	-1.190E-11	-5.066E-15	-9.677E-13
40000.	3.341E-07	-1.223E-09	-7.437E-10	-3.519E-10	-1.266E-10	-2.718E-11	6.884E-12
70000.	3.078E-07	-1.814E-10	-1.874E-10	-1.343E-10	-6.632E-11	-1.942E-11	5.742E-12
100000.	2.773E-07	-9.635E-10	-5.689E-10	-2.648E-10	-1.012E-10	-3.112E-11	-8.394E-12
200000.	1.526E-07	-1.282E-10	-6.987E-11	-2.851E-11	-6.813E-12	1.020E-12	1.154E-12
500000.	2.208E-08	6.897E-11	4.935E-11	2.919E-11	1.464E-11	6.395E-12	2.678E-12

See appendix for Chebychev fit details.

$He + O^{4+} \rightarrow O^{3+} + He^{+}$



Total Electron Capture Cross Sections for
$O^{5+} + He \rightarrow O^{4+} + He^{+}$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
4.0E+02	2.78E+07	2.41E-15
7.0E+02	3.68E+07	2.25E-15
1.0E+03	4.39E+07	2.12E-15
1.3E+03	4.91E+07	2.05E-15
2.0E+03	6.21E+07	1.85E-15
4.0E+03	8.79E+07	1.66E-15
7.0E+03	1.16E+08	1.51E-15
1.0E+04	1.39E+08	1.43E-15
2.0E+04	1.96E+08	1.27E-15
4.0E+04	2.78E+08	1.10E-15
7.0E+04	3.68E+08	8.75E-16
1.0E+05	4.39E+08	7.12E-16
2.0E+05	6.21E+08	3.19E-16
4.0E+05	8.78E+08	4.50E-17
7.0E+05	1.16E+09	4.36E-18
1.0E+06	1.39E+09	8.46E-19
2.0E+06	1.96E+09	2.98E-20
2.6E+06	2.24E+09	9.33E-21

References: E.22, E.26, E.39, E.42, E.43, E.44, T.9, T.47

Accuracy: 30% for $4 \times 10^2 \leq E(eV/amu) < 7 \times 10^4$; 25% for $E \geq 7 \times 10^4$ eV/amu

Note: In the energy region $(5\text{-}8) \times 10^2$ eV/amu dominant population of O^{4+} 2s3l levels has been observed [E.27]. This feature of the process is expected to persist down to energies as low as ~ 10 eV/amu and up to energies as high as ~ 10^4 eV/amu. The multitude of final states within the n=3 subshell provides no drastic changes in the total cross section magnitude down to energies where capture to the n=4 shell becomes important.

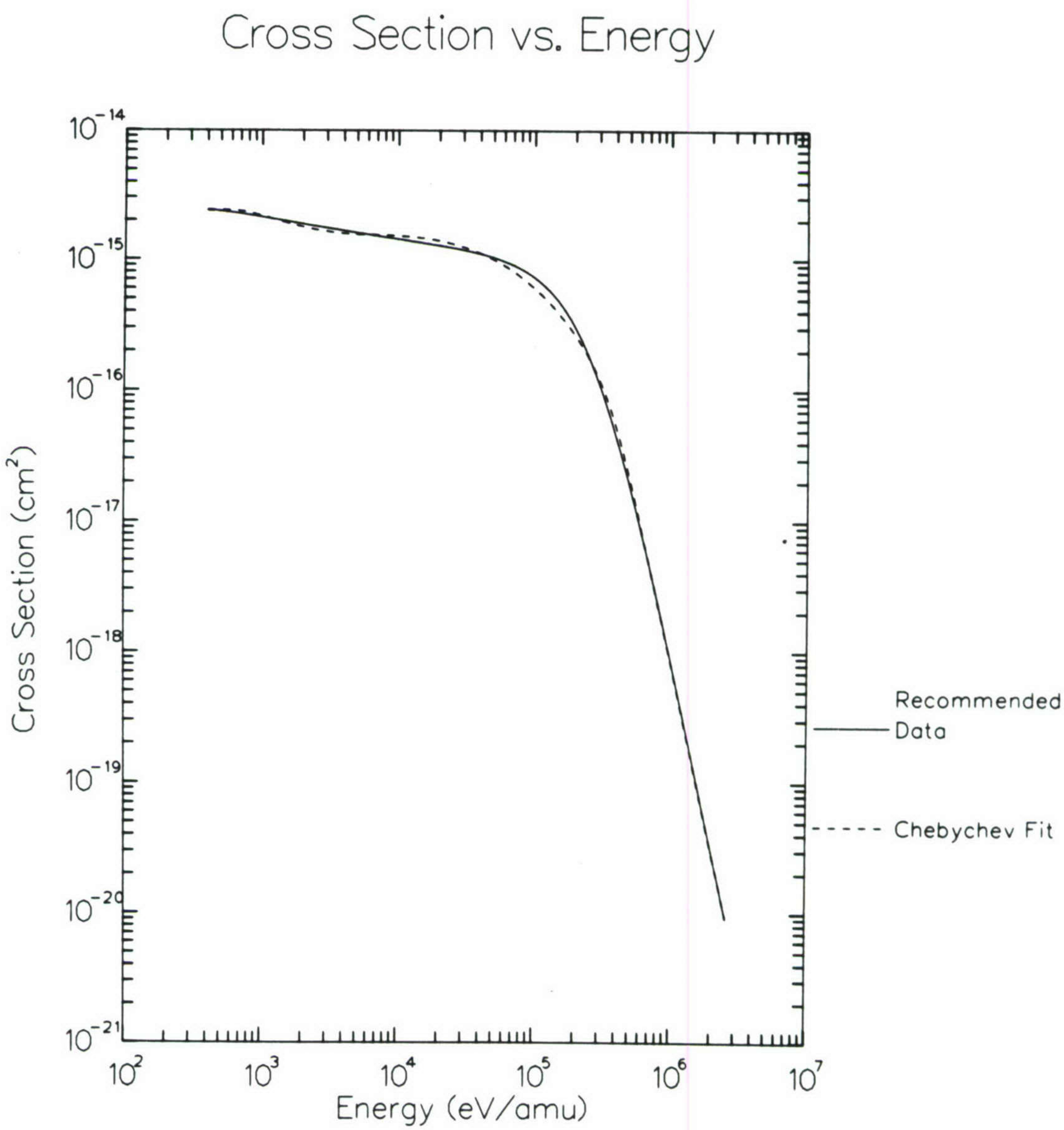
For Chebychev fits of the above cross sections it is necessary to use the following parameters.
E_{min} = 4.0E+02 eV/amu, E_{max} = 2.6E+06 eV/amu

Chebychev Fitting Parameters for Cross Sections

C1	C2	C3	C4	C5	C6	C7	C8	C9
2.156E-15	-1.316E-15	9.462E-17	9.507E-17	1.159E-16	-4.220E-18	-1.131E-16	4.718E-17	2.710E-18

The fit represents the above cross sections with an rms deviation of 9.1%.
The maximum deviation is 22.5% at 4.0E+05 eV/amu.
See appendix for Chebychev fit details.

$O^{5+} + He \rightarrow O^{4+} + He^{+}$



Total Electron Capture Rate Coefficients for
$O^{5+} + He \rightarrow O^{4+} + He^{+}$

Maxwellian - Maxwellian Rate Coefficients (cm^3/s)

O^{5+} Temp. (eV)	Equal Temp.	He Temp. (eV) 1.	10.	100.	1000.	5000.	10000.	20000.
1.4E+02	2.83E-08	9.88E-09*	1.20E-08*	2.44E-08	6.07E-08	1.05E-07	1.32E-07	1.67E-07
1.6E+02	2.99E-08	1.09E-08*	1.28E-08*	2.48E-08	6.08E-08	1.05E-07	1.32E-07	1.67E-07
3.2E+02	4.14E-08	1.79E-08	1.92E-08	2.83E-08	6.17E-08	1.06E-07	1.33E-07	1.67E-07
4.0E+02	4.55E-08	2.06E-08	2.16E-08	2.99E-08	6.21E-08	1.06E-07	1.33E-07	1.67E-07
8.0E+02	5.99E-08	3.00E-08	3.07E-08	3.64E-08	6.42E-08	1.06E-07	1.33E-07	1.67E-07
1.1E+03	6.79E-08	3.53E-08	3.58E-08	4.05E-08	6.57E-08	1.07E-07	1.33E-07	1.67E-07
1.6E+03	7.71E-08	4.15E-08	4.19E-08	4.55E-08	6.79E-08	1.08E-07	1.34E-07	1.68E-07
3.2E+03	9.75E-08	5.50E-08	5.53E-08	5.76E-08	7.43E-08	1.10E-07	1.36E-07	1.69E-07
6.4E+03	1.23E-07	7.12E-08	7.14E-08	7.28E-08	8.44E-08	1.15E-07	1.39E-07	1.71E-07
1.1E+04	1.48E-07	8.65E-08	8.66E-08	8.75E-08	9.58E-08	1.22E-07	1.44E-07	1.74E-07
1.6E+04	1.67E-07	9.75E-08	9.76E-08	9.83E-08	1.05E-07	1.28E-07	1.48E-07	1.77E-07
2.0E+04	1.79E-07	1.05E-07	1.05E-07	1.06E-07	1.12E-07	1.32E-07	1.51E-07	1.79E-07

Accuracy: * - Possible Error Greater Than 10%
** - Possible Error Greater Than 100%

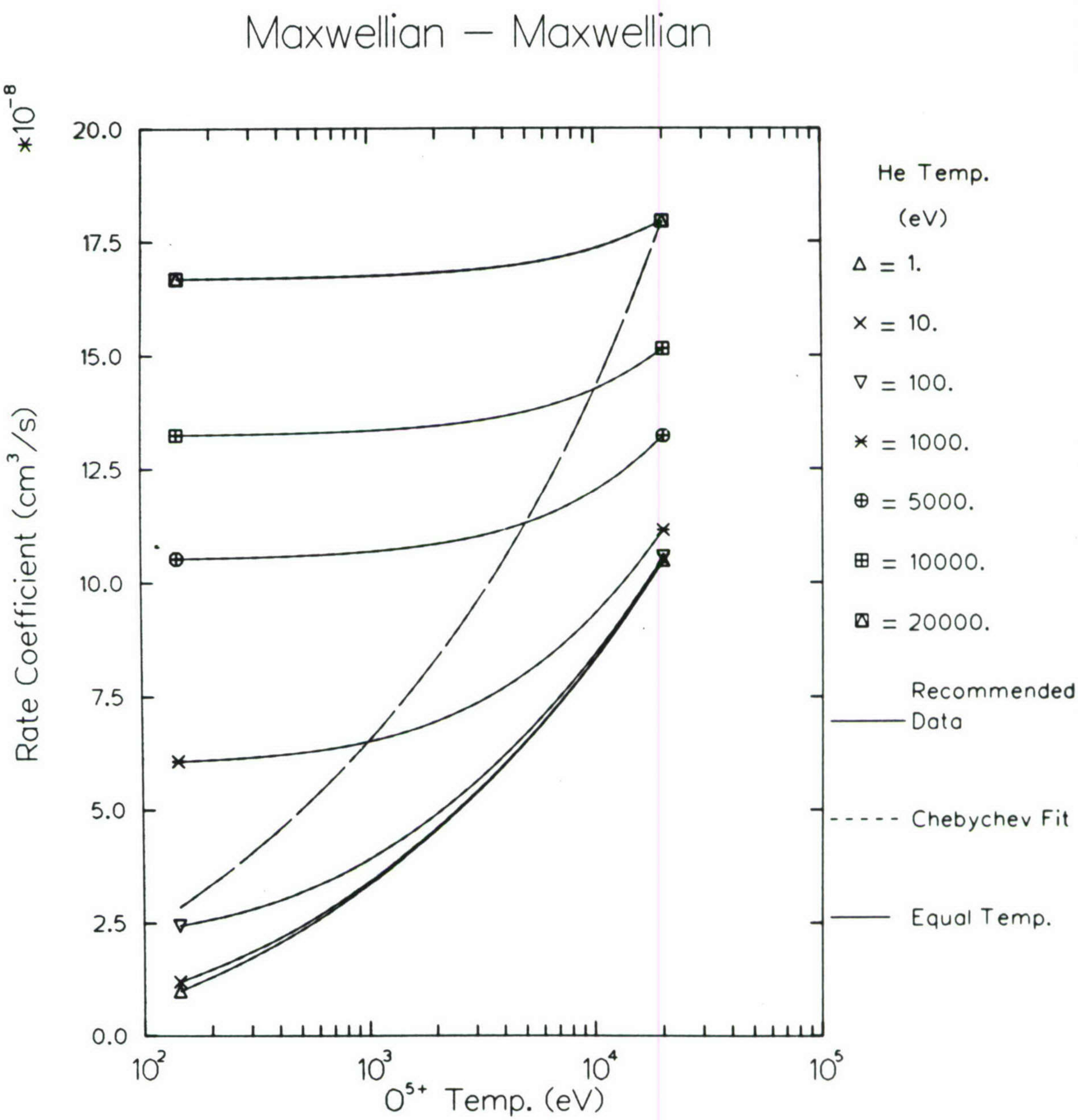
Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.4E+02 eV, E_{max} = 2.0E+04 eV

Chebychev Fitting Parameters for Rate Coefficients

He Temp. (eV)	C1	C2	C3	C4	C5	C6	C7
1.	9.972E-08	4.686E-08	7.472E-09	6.453E-10	1.139E-10	3.867E-11	-2.384E-11
10.	1.011E-07	4.593E-08	7.816E-09	5.621E-10	1.324E-10	2.936E-11	-2.007E-11
100.	1.114E-07	4.000E-08	9.283E-09	5.898E-10	1.735E-11	4.226E-11	8.699E-12
1000.	1.543E-07	2.367E-08	8.900E-09	1.759E-09	7.599E-11	-2.880E-11	9.558E-12
5000.	2.259E-07	1.179E-08	5.443E-09	1.683E-09	3.376E-10	3.105E-11	-6.495E-12
10000.	2.754E-07	8.174E-09	3.917E-09	1.306E-09	3.084E-10	4.732E-11	1.025E-12
20000.	3.405E-07	5.370E-09	2.625E-09	9.117E-10	2.343E-10	4.364E-11	4.628E-12
Equal Temp.	1.818E-07	7.351E-08	1.269E-08	2.082E-09	3.513E-10	-2.004E-11	-4.738E-11

See appendix for Chebychev fit details.

$O^{5+} + He \rightarrow O^{4+} + He^{+}$



Total Electron Capture Rate Coefficients for
$He + O^{5+} \rightarrow O^{4+} + He^{+}$

Beam - Maxwellian Rate Coefficients (cm^3/s)

O^{5+} Temp. (eV)	He Energy (eV/amu) 10000.	20000.	40000.	70000.	100000.	200000.	500000.
1.4E+02	1.99E-07	2.49E-07	3.05E-07	3.22E-07	3.13E-07	1.98E-07	1.89E-08
1.6E+02	1.99E-07	2.49E-07	3.05E-07	3.22E-07	3.12E-07	1.98E-07	1.89E-08
3.2E+02	1.99E-07	2.50E-07	3.05E-07	3.21E-07	3.12E-07	1.98E-07	1.89E-08
4.0E+02	1.98E-07	2.50E-07	3.05E-07	3.21E-07	3.12E-07	1.98E-07	1.89E-08
8.0E+02	1.99E-07	2.50E-07	3.05E-07	3.21E-07	3.12E-07	1.97E-07	1.89E-08
1.1E+03	1.99E-07	2.50E-07	3.05E-07	3.21E-07	3.12E-07	1.97E-07	1.89E-08
1.6E+03	1.99E-07	2.50E-07	3.05E-07	3.21E-07	3.12E-07	1.97E-07	1.89E-08
3.2E+03	1.99E-07	2.49E-07	3.04E-07	3.21E-07	3.11E-07	1.96E-07	1.89E-08
6.4E+03	2.00E-07	2.50E-07	3.03E-07	3.21E-07	3.10E-07	1.96E-07	1.90E-08
1.1E+04	2.02E-07	2.51E-07	3.03E-07	3.20E-07	3.09E-07	1.95E-07	1.91E-08
1.6E+04	2.04E-07	2.51E-07	3.02E-07	3.20E-07	3.08E-07	1.94E-07	1.92E-08
2.0E+04	2.05E-07	2.52E-07	3.02E-07	3.19E-07	3.07E-07	1.93E-07	1.93E-08

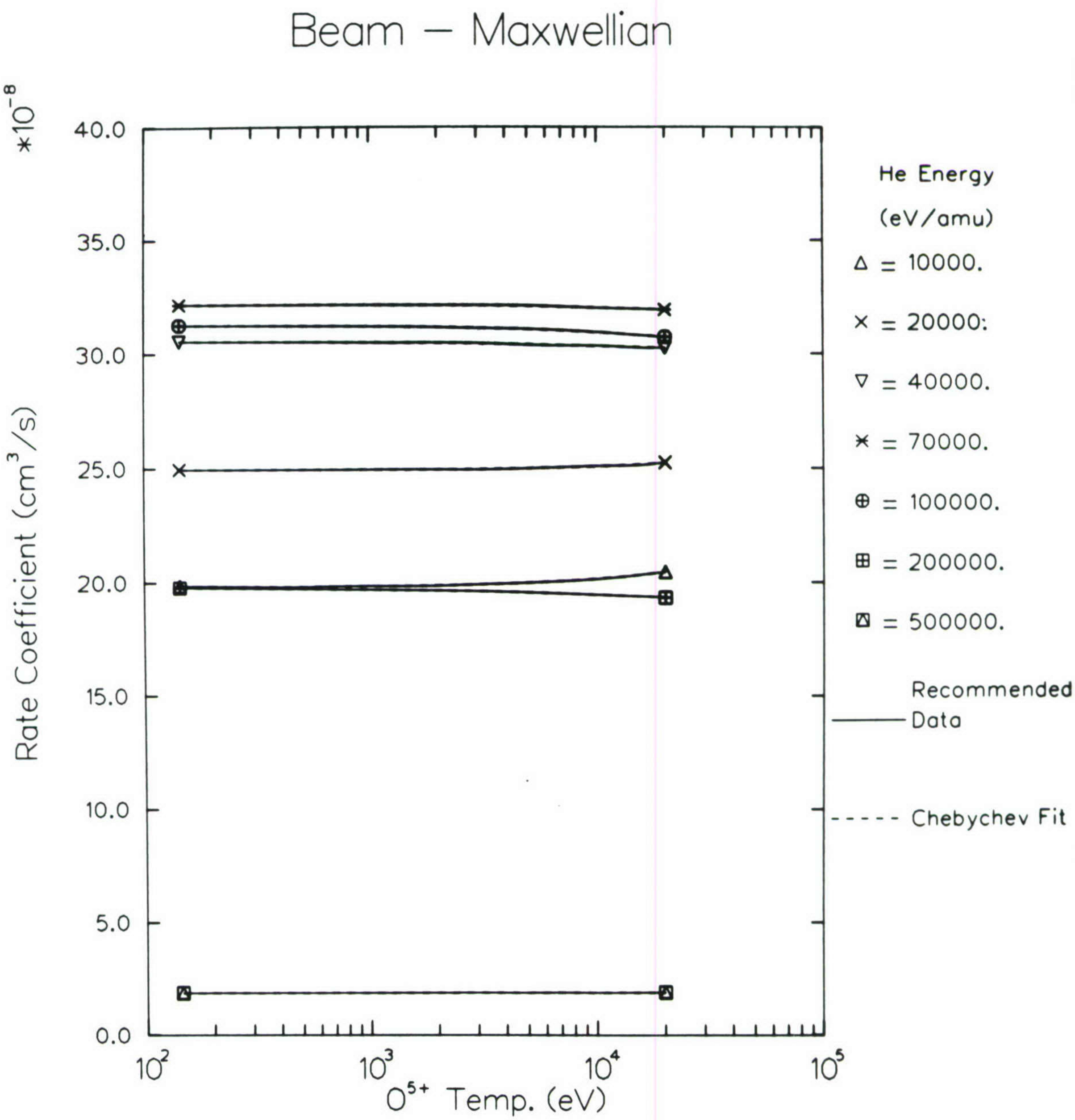
Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.4E+02 eV, E_{max} = 2.0E+04 eV

Chebychev Fitting Parameters for Rate Coefficients

He Energy (eV/amu)	C1	C2	C3	C4	C5	C6	C7
10000.	4.003E-07	2.649E-09	1.401E-09	4.118E-10	1.608E-10	-6.095E-11	-2.571E-11
20000.	5.002E-07	1.092E-09	5.968E-10	2.999E-10	8.807E-11	-5.643E-11	1.081E-10
40000.	6.084E-07	-1.521E-09	-4.284E-10	-2.369E-11	6.162E-11	5.539E-11	-1.094E-12
70000.	6.416E-07	-1.084E-09	-5.000E-10	-1.369E-10	2.024E-11	5.854E-11	2.102E-11
100000.	6.215E-07	-2.427E-09	-9.846E-10	-2.681E-10	-5.428E-11	-3.650E-11	9.425E-11
200000.	3.925E-07	-2.062E-09	-6.401E-10	-1.319E-10	-1.970E-11	-5.646E-12	-2.696E-11
500000.	3.799E-08	1.692E-10	8.553E-11	3.255E-11	1.081E-11	3.657E-12	1.023E-12

See appendix for Chebychev fit details.

$He + O^{5+} \rightarrow O^{4+} + He^{+}$



Total Electron Capture Cross Sections for
$O^{6+} + He \rightarrow O^{5+} + He^{+}$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
4.8E+02	3.04E+07	9.35E-16
7.0E+02	3.68E+07	1.03E-15
1.0E+03	4.39E+07	1.10E-15
1.3E+03	4.91E+07	1.13E-15
2.0E+03	6.21E+07	1.23E-15
4.0E+03	8.79E+07	1.24E-15
7.0E+03	1.16E+08	1.22E-15
1.0E+04	1.39E+08	1.29E-15
2.0E+04	1.96E+08	1.40E-15
4.0E+04	2.78E+08	1.19E-15
7.0E+04	3.68E+08	9.73E-16
1.0E+05	4.39E+08	7.78E-16
2.0E+05	6.21E+08	3.88E-16
4.0E+05	8.78E+08	7.06E-17
7.0E+05	1.16E+09	6.52E-18
1.0E+06	1.39E+09	1.23E-18
2.0E+06	1.96E+09	4.03E-20
2.7E+06	2.28E+09	8.93E-21

References: E.22, E.26, E.29, E.35, E.39, E.42, E.43, E.44, T.9, T.46, T.47

Accuracy: 20% over the entire energy range

Notes: (1) In the region $5x10^2 \lesssim E(eV/amu) \lesssim 7x10^3$ experimental data [E.19, E.32] indicate that capture dominantly goes to the n=3 shell of the O^{5+} product ion. It is expected that this shell will remain the most populated down to energies as low as ~ 10 eV/amu and up to energies as high as ~ $3x10^4$ eV/amu.

(2) In the region $5x10^2 \lesssim E(eV/amu) \lesssim 7x10^3$, the most-populated final subshell is O^{5+} (3p), with 3d becoming more populated at higher energies [E.19].

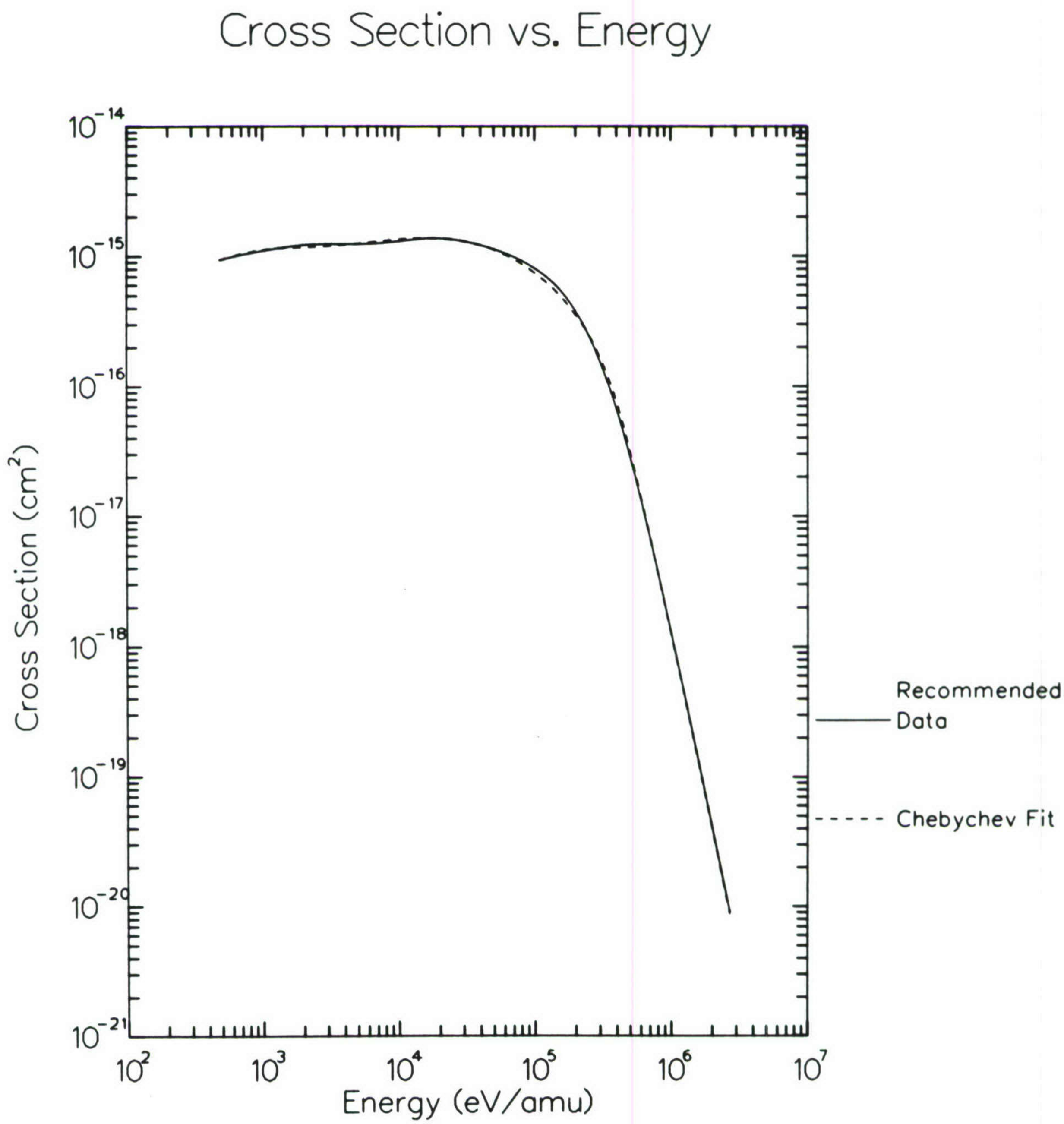
For Chebychev fits of the above cross sections it is necessary to use the following parameters.
E_{min} = 4.8E+02 eV/amu, E_{max} = 2.7E+06 eV/amu

Chebychev Fitting Parameters for Cross Sections

C1	C2	C3	C4	C5	C6	C7	C8	C9
1.389E-15	-6.451E-16	-3.055E-16	1.999E-16	1.360E-16	-2.327E-17	-8.370E-17	5.105E-18	2.195E-17

The fit represents the above cross sections with an rms deviation of 5.3%.
The maximum deviation is 14.9% at 4.0E+05 eV/amu.
See appendix for Chebychev fit details.

$O^{6+} + He \rightarrow O^{5+} + He^{+}$



Total Electron Capture Rate Coefficients for
$O^{6+} + He \rightarrow O^{5+} + He^{+}$

Maxwellian - Maxwellian Rate Coefficients (cm^3/s)

O^{6+} Temp. (eV)	Equal Temp.	He Temp. (eV) 1.	10.	100.	1000.	5000.	10000.	20000.
4.8E+02	1.33E-08	2.04E-09*	2.27E-09*	4.54E-09	2.29E-08	6.56E-08	9.65E-08	1.42E-07
8.0E+02	2.09E-08	4.06E-09	4.29E-09	6.54E-09	2.42E-08	6.62E-08	9.69E-08	1.42E-07
1.0E+03	2.58E-08	5.57E-09	5.79E-09	7.99E-09	2.52E-08	6.66E-08	9.72E-08	1.42E-07
1.6E+03	3.56E-08	8.95E-09	9.16E-09	1.12E-08	2.73E-08	6.76E-08	9.80E-08	1.43E-07
3.2E+03	5.65E-08	1.73E-08	1.75E-08	1.92E-08	3.30E-08	7.05E-08	1.00E-07	1.44E-07
6.4E+03	8.46E-08	3.03E-08	3.04E-08	3.16E-08	4.27E-08	7.59E-08	1.04E-07	1.47E-07
7.7E+03	9.37E-08	3.46E-08	3.47E-08	3.58E-08	4.62E-08	7.80E-08	1.06E-07	1.49E-07
1.1E+04	1.16E-07	4.49E-08	4.50E-08	4.60E-08	5.47E-08	8.34E-08	1.10E-07	1.52E-07
1.6E+04	1.41E-07	5.65E-08	5.66E-08	5.73E-08	6.46E-08	9.04E-08	1.16E-07	1.56E-07
2.0E+04	1.60E-07	6.46E-08	6.47E-08	6.54E-08	7.19E-08	9.58E-08	1.20E-07	1.60E-07

Accuracy: * - Possible Error Greater Than 10%
** - Possible Error Greater Than 100%

Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 4.8E+02 eV, E_{max} = 2.0E+04 eV

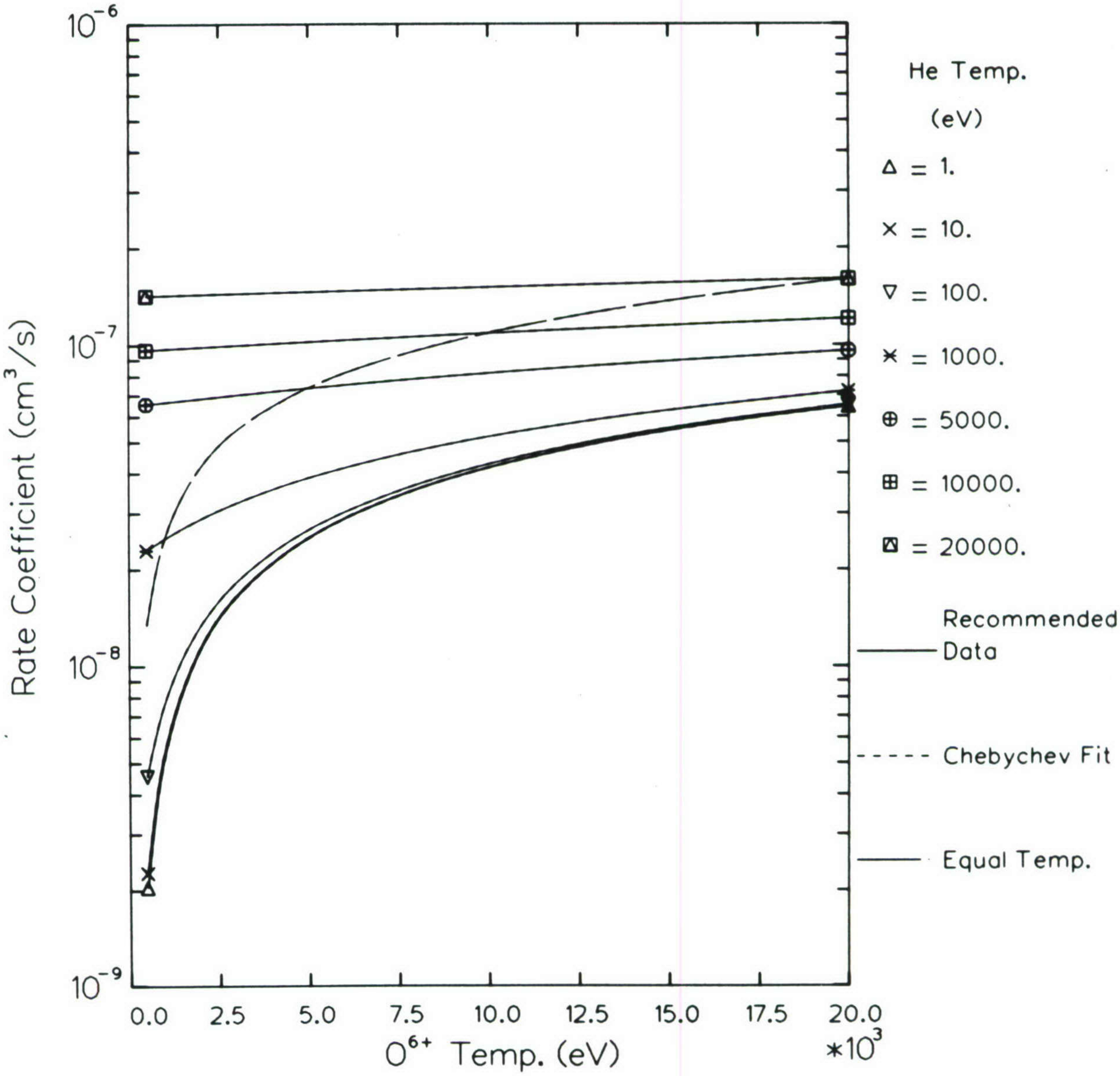
Chebychev Fitting Parameters for Rate Coefficients

He Temp. (eV)	C1	C2	C3	C4	C5	C6	C7
1.	5.017E-08	3.038E-08	8.264E-09	9.298E-10	8.882E-12	-8.321E-12	-1.237E-11
10.	5.049E-08	3.030E-08	8.251E-09	9.386E-10	7.955E-12	-9.481E-12	-1.219E-11
100.	5.366E-08	2.944E-08	8.150E-09	1.009E-09	2.387E-12	-1.839E-11	-1.033E-11
1000.	7.998E-08	2.326E-08	7.389E-09	1.235E-09	3.965E-11	-2.370E-11	5.403E-13
5000.	1.506E-07	1.386E-08	5.181E-09	1.259E-09	2.031E-10	1.989E-11	-1.870E-12
10000.	2.079E-07	1.077E-08	4.208E-09	1.130E-09	2.203E-10	5.269E-12	-5.477E-12
20000.	2.948E-07	8.028E-09	3.213E-09	8.886E-10	1.821E-10	2.515E-11	-9.690E-12
Equal Temp.	1.407E-07	7.070E-08	1.572E-08	2.443E-09	5.938E-10	7.429E-11	-9.755E-11

See appendix for Chebychev fit details.

$O^{6+} + He \rightarrow O^{5+} + He^{+}$

Maxwellian – Maxwellian



Total Electron Capture Rate Coefficients for
He + O^{6+} -> O^{5+} + He^{+}

Beam - Maxwellian Rate Coefficients (cm^3/s)

O^{6+} Temp. (eV)	He Energy (eV/amu) 10000.	20000.	40000.	70000.	100000.	200000.	500000.
4.8E+02	1.79E-07	2.74E-07	3.31E-07	3.57E-07	3.42E-07	2.40E-07	2.99E-08
8.0E+02	1.79E-07	2.74E-07	3.31E-07	3.57E-07	3.42E-07	2.40E-07	2.99E-08
1.0E+03	1.80E-07	2.74E-07	3.31E-07	3.57E-07	3.41E-07	2.40E-07	2.99E-08
1.6E+03	1.80E-07	2.74E-07	3.31E-07	3.57E-07	3.41E-07	2.39E-07	2.99E-08
3.2E+03	1.81E-07	2.73E-07	3.32E-07	3.56E-07	3.41E-07	2.39E-07	3.00E-08
6.4E+03	1.83E-07	2.73E-07	3.31E-07	3.55E-07	3.40E-07	2.38E-07	3.01E-08
7.7E+03	1.85E-07	2.72E-07	3.32E-07	3.55E-07	3.40E-07	2.37E-07	3.01E-08
1.1E+04	1.87E-07	2.73E-07	3.32E-07	3.53E-07	3.40E-07	2.37E-07	3.02E-08
1.6E+04	1.91E-07	2.72E-07	3.31E-07	3.53E-07	3.38E-07	2.35E-07	3.04E-08
2.0E+04	1.94E-07	2.72E-07	3.31E-07	3.52E-07	3.38E-07	2.35E-07	3.05E-08

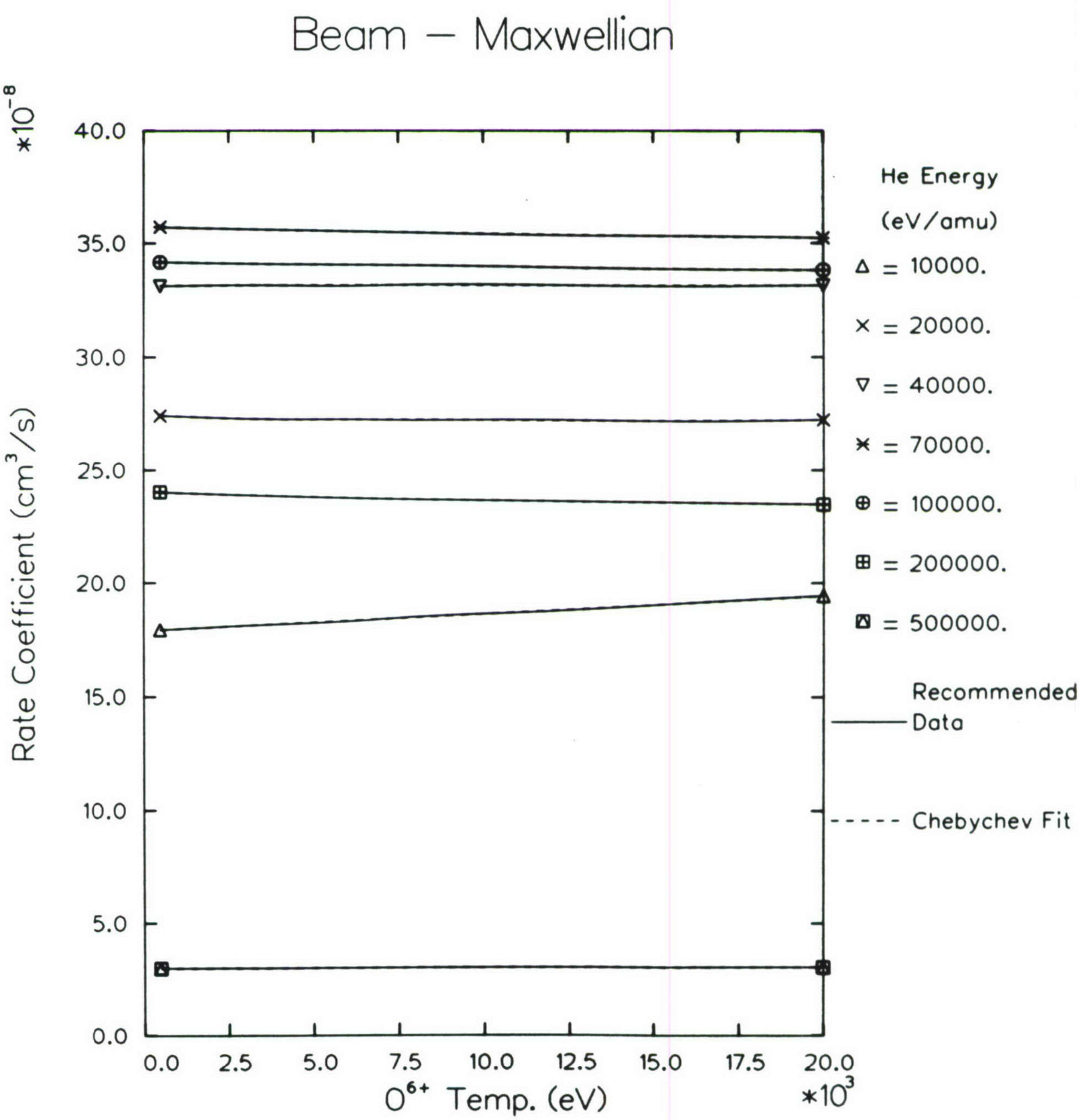
Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 4.8E+02 eV, E_{max} = 2.0E+04 eV

Chebychev Fitting Parameters for Rate Coefficients

He Energy (eV/amu)	C1	C2	C3	C4	C5	C6	C7
10000.	3.676E-07	6.692E-09	2.796E-09	8.258E-10	2.065E-10	2.986E-11	4.391E-13
20000.	5.461E-07	-1.092E-09	6.184E-11	1.749E-10	-2.789E-11	1.107E-11	2.157E-10
40000.	6.626E-07	1.566E-10	-1.827E-10	-1.423E-11	3.521E-11	-4.586E-12	1.013E-10
70000.	7.108E-07	-2.322E-09	-6.852E-10	-1.169E-10	6.242E-11	7.815E-11	-4.203E-11
100000.	6.807E-07	-1.605E-09	-6.231E-10	-1.602E-10	-5.367E-11	4.494E-11	1.746E-10
200000.	4.762E-07	-2.633E-09	-6.105E-10	-5.438E-11	-1.198E-12	-4.697E-11	-6.048E-11
500000.	6.012E-08	2.646E-10	1.095E-10	3.328E-11	9.725E-12	3.347E-12	-4.570E-13

See appendix for Chebychev fit details.

$He + O^{6+} \rightarrow O^{5+} + He^{+}$



Total Electron Capture Cross Sections for
$O^{7+} + He \rightarrow O^{6+} + He^{+}$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
5.2E+02	3.17E+07	1.17E-15
7.0E+02	3.68E+07	1.24E-15
1.0E+03	4.39E+07	1.36E-15
1.3E+03	4.91E+07	1.41E-15
2.0E+03	6.21E+07	1.56E-15
4.0E+03	8.79E+07	1.67E-15
7.0E+03	1.16E+08	1.79E-15
1.0E+04	1.39E+08	1.81E-15
2.0E+04	1.96E+08	1.78E-15
4.0E+04	2.78E+08	1.64E-15
7.0E+04	3.68E+08	1.47E-15
1.0E+05	4.39E+08	1.22E-15
2.0E+05	6.21E+08	5.55E-16
4.0E+05	8.78E+08	1.11E-16
7.0E+05	1.16E+09	1.19E-17
1.0E+06	1.39E+09	2.35E-18
2.0E+06	1.96E+09	9.38E-20
2.6E+06	2.24E+09	2.37E-20

References: E.26, E.39, E.42, E.43, E.44, T.9, T.40, T.47

Accuracy: 30% for $5x10^2 \lesssim E(eV/amu) < 3x10^4$; 20% for $E \gtrsim 3x10^4$ eV/amu

Notes: (1) In the energy region between $1x10^3$ and $3x10^4$ eV/amu there are no cross section data. Drastic variations in the cross section behavior are not expected in this region, and an accuracy of 30% is assigned to the interpolated portion.
(2) Multichannel Landau-Zener calculations [T.40] of σ at $E = 6x10^2$ eV/amu, show that the n=4 sub-shell is the most populated. This conclusion can be extended down to ~ 10 eV/amu and up to ~ $1x10^4$ eV/amu. At higher energies capture to n=3 shoud also be important.
(3) At E ~ $5x10^2$ eV/amu two-electron capture into $3\ell 3\ell'$ autoionizing states has been observed [E.45] with a cross section an order of magnitude smaller than for single capture.

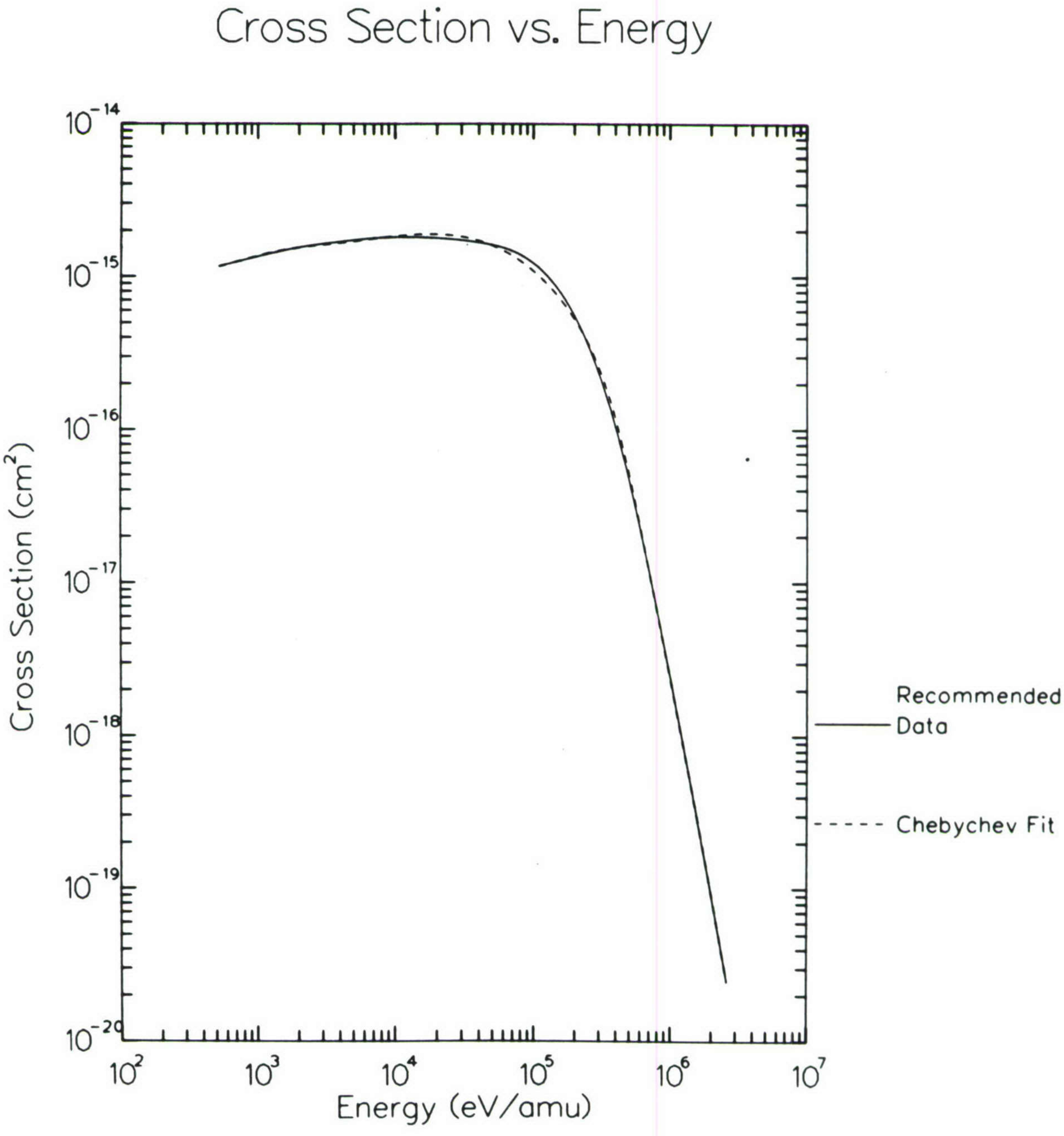
For Chebychev fits of the above cross sections it is necessary to use the following parameters.
E_{min} = 5.2E+02 eV/amu, E_{max} = 2.6E+06 eV/amu

Chebychev Fitting Parameters for Cross Sections

C1	C2	C3	C4	C5	C6	C7	C8	C9
1.859E-15	-8.156E-16	-4.828E-16	2.800E-16	2.019E-16	-3.737E-17	-1.001E-16	-1.168E-17	3.613E-17

The fit represents the above cross sections with an rms deviation of 5.3%.
The maximum deviation is 14.2% at 4.0E+05 eV/amu.
See appendix for Chebychev fit details.

$O^{7+} + He \rightarrow O^{6+} + He^{+}$



Total Electron Capture Rate Coefficients for
$O^{7+} + He \rightarrow O^{6+} + He^{+}$

Maxwellian - Maxwellian Rate Coefficients (cm^3/s)

O^{7+} Temp. (eV)	Equal Temp.	He Temp. (eV) 1.	10.	100.	1000.	5000.	10000.	20000.
4.8E+02	1.84E-08	4.67E-09*	5.05E-09*	8.30E-09	2.93E-08	8.50E-08	1.30E-07	1.93E-07
6.4E+02	2.28E-08	6.27E-09*	6.60E-09*	9.55E-09	3.01E-08	8.55E-08	1.31E-07	1.93E-07
9.6E+02	3.09E-08	8.97E-09	9.25E-09	1.18E-08	3.16E-08	8.63E-08	1.31E-07	1.94E-07
1.6E+03	4.47E-08	1.35E-08	1.37E-08	1.60E-08	3.46E-08	8.80E-08	1.32E-07	1.94E-07
3.2E+03	7.22E-08	2.29E-08	2.30E-08	2.49E-08	4.15E-08	9.22E-08	1.35E-07	1.96E-07
6.4E+03	1.13E-07	3.81E-08	3.83E-08	3.98E-08	5.38E-08	1.00E-07	1.41E-07	2.00E-07
8.3E+03	1.32E-07	4.60E-08	4.62E-08	4.76E-08	6.06E-08	1.05E-07	1.45E-07	2.03E-07
1.1E+04	1.58E-07	5.67E-08	5.68E-08	5.81E-08	6.98E-08	1.11E-07	1.50E-07	2.06E-07
1.6E+04	1.92E-07	7.23E-08	7.24E-08	7.34E-08	8.37E-08	1.21E-07	1.58E-07	2.12E-07
2.0E+04	2.16E-07	8.37E-08	8.38E-08	8.48E-08	9.42E-08	1.29E-07	1.64E-07	2.16E-07

Accuracy: * - Possible Error Greater Than 10%
** - Possible Error Greater Than 100%

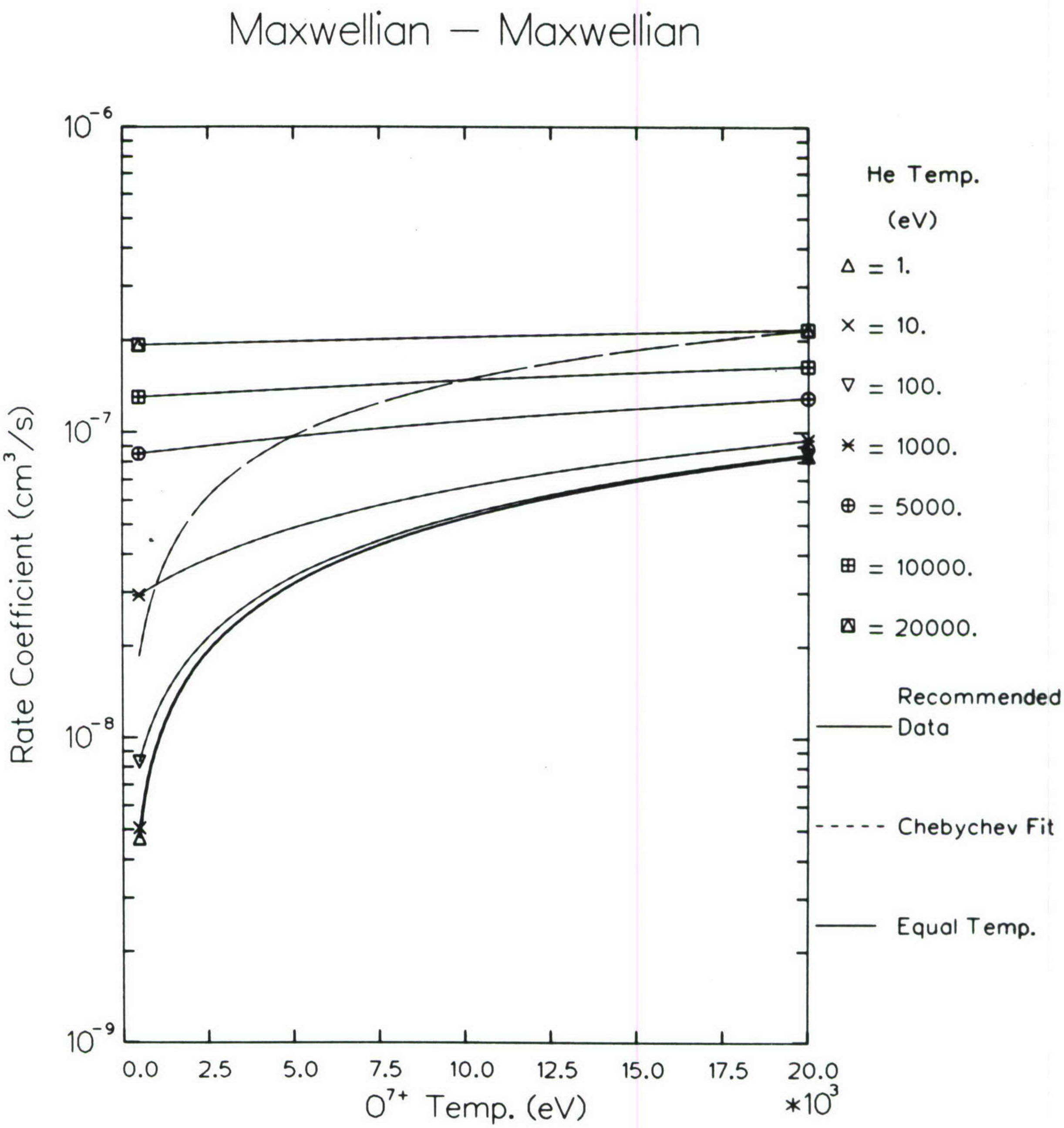
Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 4.8E+02 eV, E_{max} = 2.0E+04 eV

Chebychev Fitting Parameters for Rate Coefficients

He Temp. (eV)	C1	C2	C3	C4	C5	C6	C7
1.	6.622E-08	3.748E-08	1.094E-08	2.057E-09	1.342E-10	-1.790E-11	-8.719E-13
10.	6.664E-08	3.735E-08	1.097E-08	2.047E-09	1.373E-10	-1.840E-11	-1.777E-12
100.	7.063E-08	3.625E-08	1.107E-08	1.999E-09	1.519E-10	-1.965E-11	-5.228E-12
1000.	1.024E-07	3.034E-08	1.034E-08	2.071E-09	2.020E-10	-2.296E-12	1.667E-12
5000.	1.985E-07	2.028E-08	7.641E-09	1.885E-09	2.787E-10	3.203E-11	2.802E-13
10000.	2.819E-07	1.529E-08	5.947E-09	1.533E-09	2.633E-10	3.156E-11	4.493E-12
20000.	4.004E-07	1.048E-08	4.155E-09	1.136E-09	2.360E-10	5.083E-11	1.936E-11
Equal Temp.	1.882E-07	9.650E-08	2.333E-08	2.530E-09	-9.764E-11	-9.193E-11	-2.548E-11

See appendix for Chebychev fit details.

$O^{7+} + He \rightarrow O^{6+} + He^{+}$



Total Electron Capture Rate Coefficients for
$He + O^{7+} \rightarrow O^{6+} + He^{+}$

Beam - Maxwellian Rate Coefficients (cm^3/s)

O^{7+} Temp. (eV)	He Energy (eV/amu) 10000.	20000.	40000.	70000.	100000.	200000.	500000.
4.8E+02	2.52E-07	3.50E-07	4.56E-07	5.39E-07	5.35E-07	3.44E-07	4.95E-08
6.4E+02	2.52E-07	3.49E-07	4.56E-07	5.39E-07	5.35E-07	3.44E-07	4.95E-08
9.6E+02	2.52E-07	3.50E-07	4.56E-07	5.39E-07	5.35E-07	3.44E-07	4.95E-08
1.6E+03	2.52E-07	3.50E-07	4.56E-07	5.38E-07	5.35E-07	3.44E-07	4.95E-08
3.2E+03	2.53E-07	3.50E-07	4.56E-07	5.37E-07	5.33E-07	3.43E-07	4.96E-08
6.4E+03	2.55E-07	3.51E-07	4.55E-07	5.36E-07	5.32E-07	3.42E-07	4.97E-08
8.3E+03	2.56E-07	3.51E-07	4.57E-07	5.35E-07	5.31E-07	3.42E-07	4.98E-08
1.1E+04	2.58E-07	3.53E-07	4.57E-07	5.33E-07	5.30E-07	3.42E-07	4.99E-08
1.6E+04	2.61E-07	3.53E-07	4.56E-07	5.32E-07	5.27E-07	3.41E-07	5.01E-08
2.0E+04	2.63E-07	3.55E-07	4.58E-07	5.31E-07	5.27E-07	3.40E-07	5.03E-08

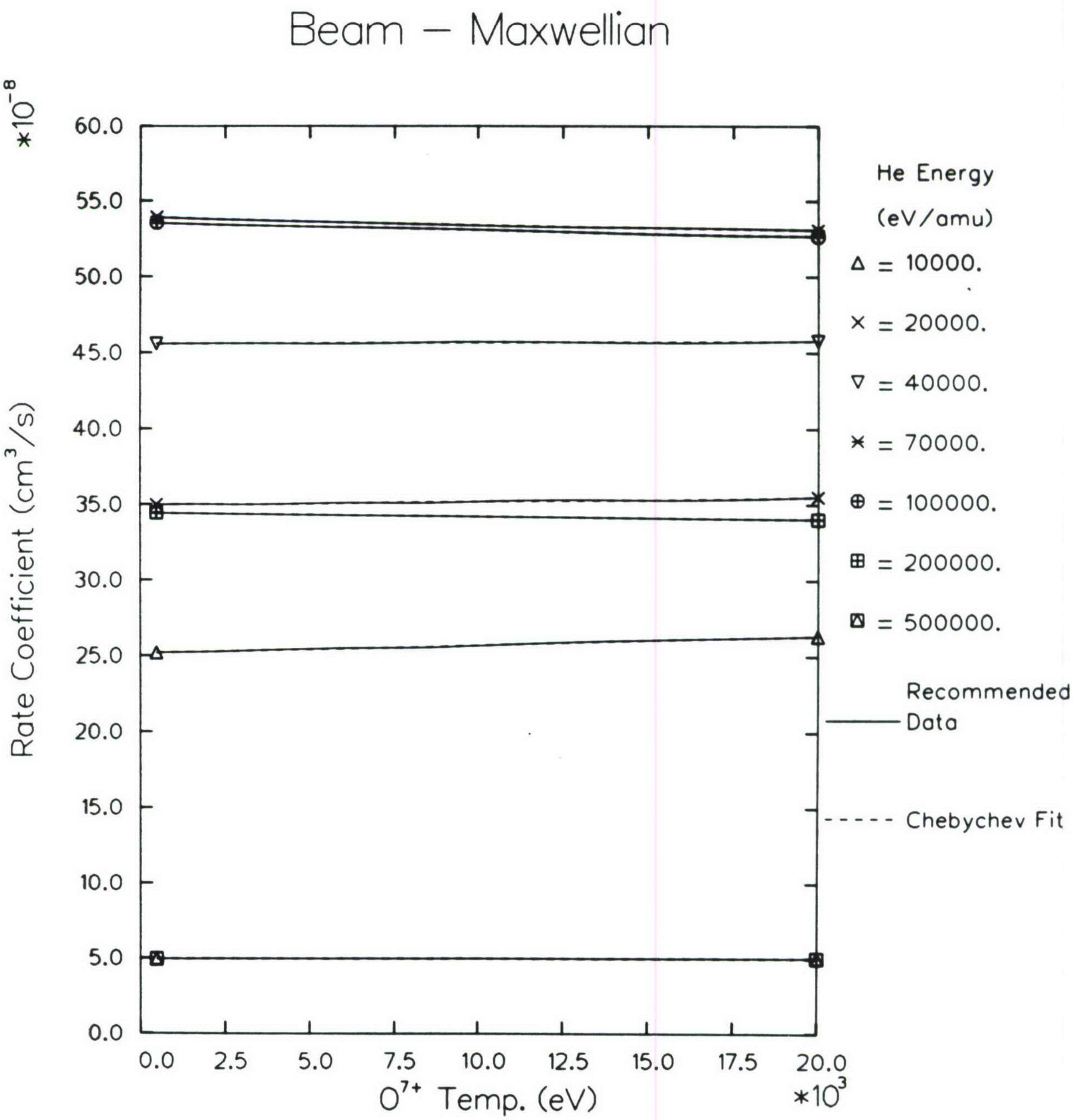
Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 4.8E+02 eV, E_{max} = 2.0E+04 eV

Chebychev Fitting Parameters for Rate Coefficients

He Energy (eV/amu)	C1	C2	C3	C4	C5	C6	C7
10000.	5.106E-07	5.136E-09	2.347E-09	6.565E-10	1.541E-10	5.710E-12	-1.982E-10
20000.	7.020E-07	2.181E-09	1.082E-09	4.843E-10	5.711E-11	1.097E-11	2.500E-10
40000.	9.124E-07	7.468E-10	3.605E-10	2.095E-10	7.691E-11	3.114E-11	1.256E-10
70000.	1.072E-06	-4.122E-09	-1.144E-09	-1.723E-10	1.028E-10	8.799E-11	-4.380E-11
100000.	1.065E-06	-4.137E-09	-1.432E-09	-3.759E-10	-1.284E-10	1.129E-10	2.258E-10
200000.	6.857E-07	-1.823E-09	-4.943E-10	-8.457E-11	-3.165E-11	-4.129E-11	-1.582E-11
500000.	9.942E-08	3.612E-10	1.491E-10	4.608E-11	1.423E-11	4.590E-12	-3.793E-13

See appendix for Chebychev fit details.

$He + O^{7+} \rightarrow O^{6+} + He^{+}$



Total Electron Capture Cross Sections for
$O^{8+} + He \rightarrow O^{7+} + He^{+}$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
7.0E+02	3.68E+07	2.81E-15
1.0E+03	4.39E+07	2.97E-15
1.3E+03	4.91E+07	3.05E-15
2.0E+03	6.21E+07	3.07E-15
4.0E+03	8.79E+07	3.04E-15
7.0E+03	1.16E+08	2.85E-15
1.0E+04	1.39E+08	2.60E-15
2.0E+04	1.96E+08	2.19E-15
4.0E+04	2.78E+08	2.11E-15
7.0E+04	3.68E+08	2.01E-15
1.0E+05	4.39E+08	1.77E-15
2.0E+05	6.21E+08	7.94E-16
4.0E+05	8.78E+08	1.26E-16
7.0E+05	1.16E+09	1.64E-17
1.0E+06	1.39E+09	3.91E-18
2.0E+06	1.96E+09	2.10E-19
3.0E+06	2.40E+09	3.93E-20

References: E.26, E.33, E.39, E.42, E.44, E.46, T.9, T.41, T.42, T.43, T.47, T.48

Accuracy: 30% for $7x10^2 \lesssim E(eV/amu) \lesssim 2x10^4$; 25% for $2x10^4 < E(eV/amu) < 5x10^5$; 15% for $E \gtrsim 5x10^5$ eV/amu

Notes: (1) Calculations [T.48] indicate that in the region $2x10^2 \lesssim E(eV/amu) \lesssim 5x10^4$, the most populated final shell by single capture is n=4.
(2) In the same energy region, double electron capture is predicted to be negligible with respect to single electron capture [T.48].

For Chebychev fits of the above cross sections it is necessary to use the following parameters.
E_{min} = 7.0E+02 eV/amu, E_{max} = 3.0E+06 eV/amu

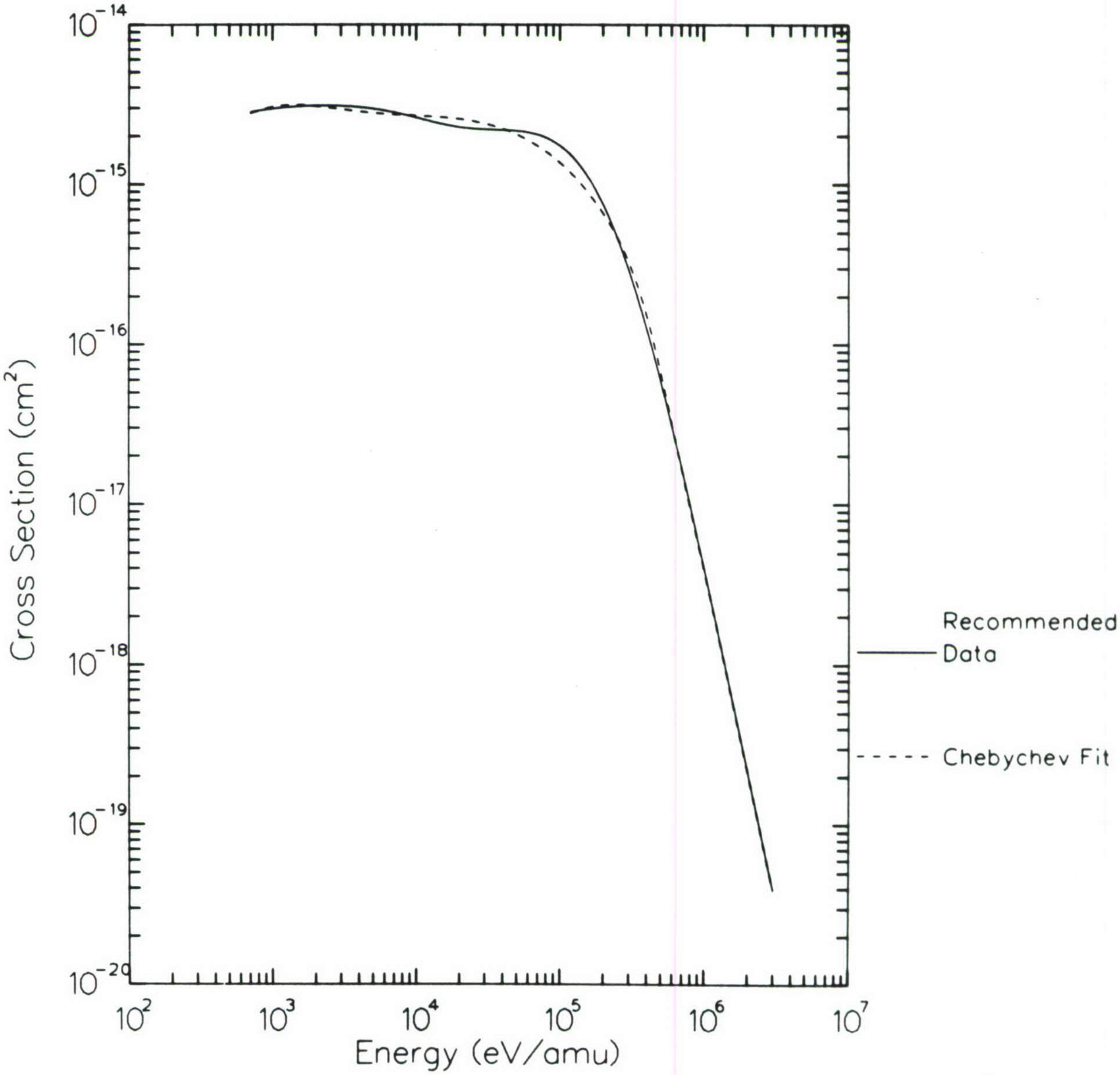
Chebychev Fitting Parameters for Cross Sections

C1	C2	C3	C4	C5	C6	C7	C8	C9
3.182E-15	-1.782E-15	-2.138E-16	3.922E-16	1.176E-16	-1.844E-17	-1.503E-16	2.997E-17	3.334E-17

The fit represents the above cross sections with an rms deviation of 11.4%.
The maximum deviation is 26.1% at 4.0E+05 eV/amu.
See appendix for Chebychev fit details.

$O^{8+} + He \rightarrow O^{7+} + He^{+}$

Cross Section vs. Energy



Total Electron Capture Rate Coefficients for
$O^{8+} + He \rightarrow O^{7+} + He^{+}$

Maxwellian - Maxwellian Rate Coefficients (cm^3/s)

O^{8+} Temp. (eV)	Equal Temp.	He Temp. (eV) 1.	10.	100.	1000.	5000.	10000.	20000.
1.6E+03	9.37E-08	2.14E-08*	2.20E-08*	2.78E-08*	7.22E-08	1.70E-07	2.31E-07	2.99E-07
3.2E+03	1.44E-07	4.49E-08	4.53E-08	4.99E-08	8.70E-08	1.76E-07	2.35E-07	3.01E-07
6.4E+03	2.06E-07	7.99E-08	8.02E-08	8.35E-08	1.11E-07	1.88E-07	2.42E-07	3.05E-07
1.1E+04	2.60E-07	1.17E-07	1.17E-07	1.19E-07	1.40E-07	2.04E-07	2.52E-07	3.10E-07
1.6E+04	2.97E-07	1.44E-07	1.44E-07	1.46E-07	1.63E-07	2.17E-07	2.60E-07	3.16E-07
2.0E+04	3.20E-07	1.63E-07	1.63E-07	1.65E-07	1.79E-07	2.27E-07	2.67E-07	3.20E-07

Accuracy: * - Possible Error Greater Than 10%
** - Possible Error Greater Than 100%

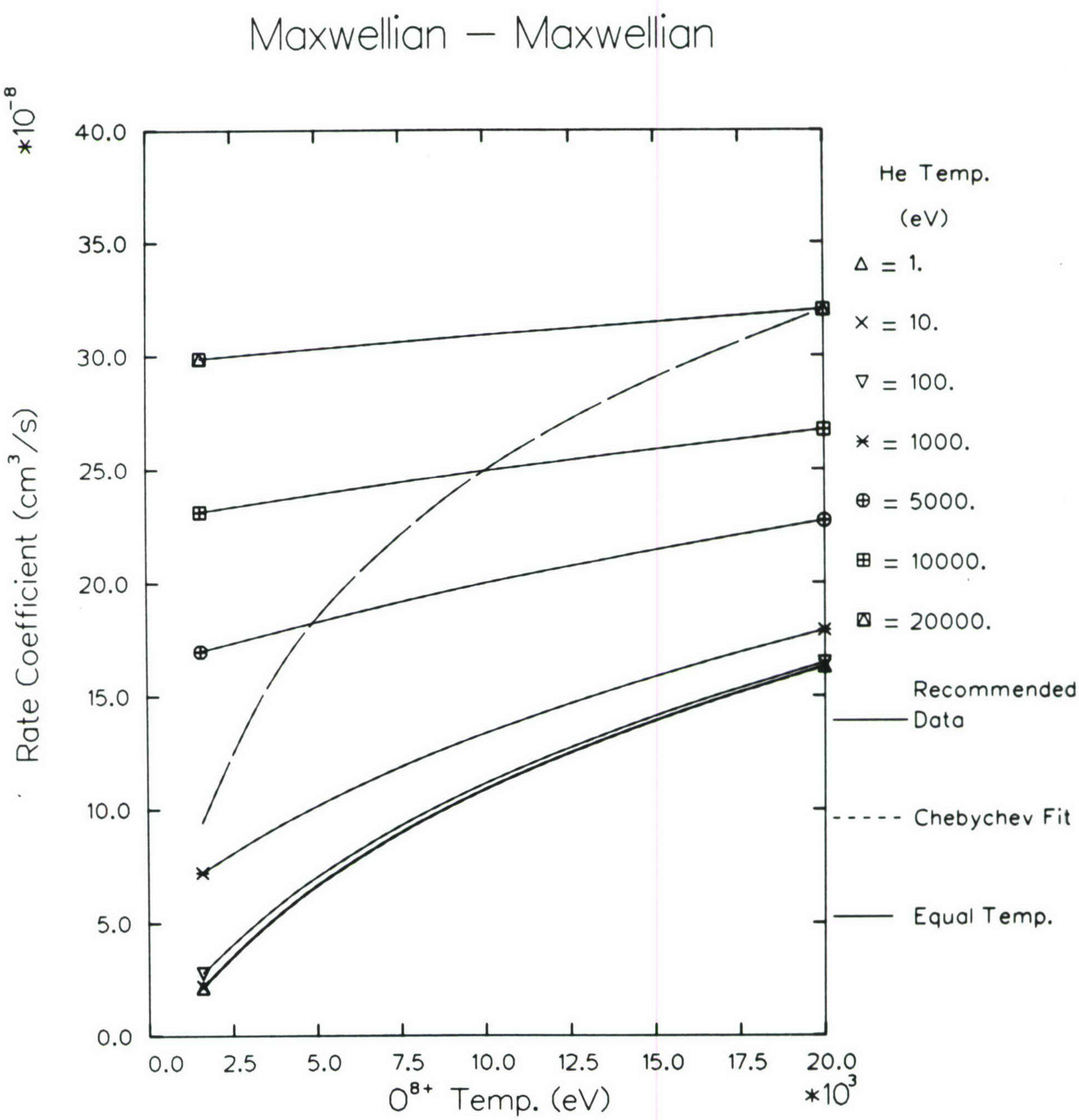
Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.6E+03 eV, E_{max} = 2.0E+04 eV

Chebychev Fitting Parameters for Rate Coefficients

He Temp. (eV)	C1	C2	C3	C4	C5	C6	C7
1.	1.652E-07	7.077E-08	9.759E-09	3.140E-11	-7.576E-11	8.156E-11	
10.	1.659E-07	7.055E-08	9.770E-09	3.658E-11	-7.594E-11	8.227E-11	
100.	1.731E-07	6.844E-08	9.843E-09	1.053E-10	-6.210E-11	-2.919E-12	
1000.	2.321E-07	5.305E-08	9.720E-09	5.534E-10	-6.139E-11	-5.704E-11	
5000.	3.839E-07	2.797E-08	6.642E-09	8.041E-10	7.686E-12	-2.100E-11	
10000.	4.894E-07	1.742E-08	4.493E-09	6.783E-10	4.977E-11	-6.009E-12	
20000.	6.131E-07	1.029E-08	2.869E-09	5.177E-10	6.247E-11	4.658E-12	
Equal Temp.	4.011E-07	1.140E-07	6.339E-09	-9.109E-10	9.156E-11	2.059E-10	

See appendix for Chebychev fit details.

$O^{8+} + He \rightarrow O^{7+} + He^{+}$



Total Electron Capture Rate Coefficients for
$He + O^{8+} \rightarrow O^{7+} + He^{+}$

Beam - Maxwellian Rate Coefficients (cm^3/s)

O^{8+} Temp. (eV)	He Energy (eV/amu) 10000.	20000.	40000.	70000.	100000.	200000.	500000.
1.6E+03	3.62E-07	4.33E-07	5.83E-07	7.36E-07	7.74E-07	4.92E-07	5.83E-08
3.2E+03	3.63E-07	4.33E-07	5.85E-07	7.35E-07	7.72E-07	4.91E-07	5.84E-08
6.4E+03	3.64E-07	4.37E-07	5.84E-07	7.34E-07	7.70E-07	4.89E-07	5.85E-08
1.1E+04	3.65E-07	4.40E-07	5.87E-07	7.31E-07	7.66E-07	4.88E-07	5.87E-08
1.6E+04	3.67E-07	4.43E-07	5.87E-07	7.30E-07	7.61E-07	4.87E-07	5.89E-08
2.0E+04	3.68E-07	4.47E-07	5.90E-07	7.29E-07	7.59E-07	4.86E-07	5.91E-08

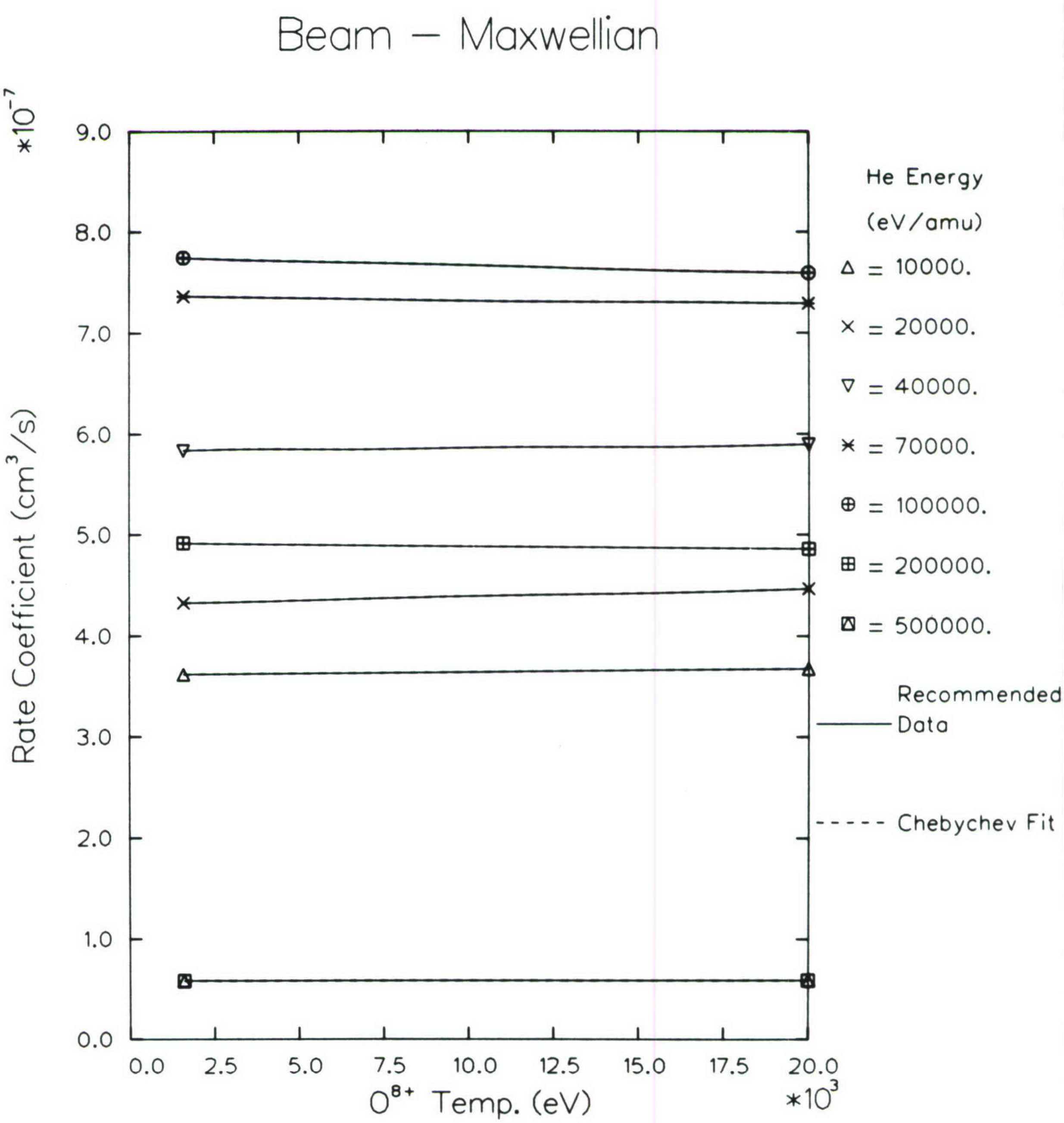
Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.6E+03 eV, E_{max} = 2.0E+04 eV

Chebychev Fitting Parameters for Rate Coefficients

He Energy (eV/amu)	C1	C2	C3	C4	C5	C6	C7
10000.	7.279E-07	2.954E-09	5.779E-10	2.777E-10	1.089E-10	-2.843E-10	
20000.	8.755E-07	6.003E-09	2.105E-09	8.481E-11	-1.727E-10	9.427E-10	
40000.	1.173E-06	8.464E-10	1.363E-09	7.122E-10	-1.223E-09	1.472E-09	
70000.	1.465E-06	-2.752E-09	-9.787E-10	2.110E-10	8.784E-10	-1.030E-09	
100000.	1.537E-06	-7.768E-09	-1.557E-09	-4.521E-10	-6.051E-11	6.907E-10	
200000.	9.788E-07	-2.877E-09	-3.944E-10	-5.812E-11	-2.118E-10	1.031E-10	
500000.	1.171E-07	4.106E-10	1.110E-10	3.253E-11	2.610E-11	-2.341E-11	

See appendix for Chebychev fit details.

He + O^{8+} -> O^{7+} + He^{+}


Beam – Maxwellian
*10^-7
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
Rate Coefficient (cm^3/s)
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
*10^3
O^8+ Temp. (eV)
He Energy
(eV/amu)
△ = 10000.
× = 20000.
▽ = 40000.
✳ = 70000.
⊕ = 100000.
⊞ = 200000.
⊠ = 500000.
Recommended Data
Chebychev Fit

Total Electron Capture Cross Sections for
$C^+ + H_2 \rightarrow C + H_2^+$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
1.0E+00	1.39E+06	9.79E-17
2.0E+00	1.96E+06	1.51E-16
4.0E+00	2.78E+06	2.11E-16
7.0E+00	3.68E+06	2.79E-16
1.0E+01	4.39E+06	3.24E-16
2.0E+01	6.21E+06	3.78E-16
4.0E+01	8.79E+06	3.63E-16
7.0E+01	1.16E+07	3.30E-16
1.0E+02	1.39E+07	3.07E-16
2.0E+02	1.96E+07	2.62E-16
4.0E+02	2.78E+07	2.40E-16
7.0E+02	3.68E+07	2.69E-16
1.0E+03	4.39E+07	3.34E-16
1.7E+03	5.66E+07	5.00E-16
2.0E+03	6.21E+07	5.64E-16
4.0E+03	8.79E+07	8.49E-16
7.0E+03	1.16E+08	8.23E-16
1.0E+04	1.39E+08	7.31E-16
2.0E+04	1.96E+08	4.97E-16
4.0E+04	2.78E+08	2.63E-16
7.0E+04	3.68E+08	1.04E-16
1.0E+05	4.39E+08	4.94E-17
2.0E+05	6.21E+08	7.34E-18

References: E.1, E.2, E.3, E.47, E.48, E.49, E.50, E.51

Accuracy: 50% for $1 < E(eV/amu) \leq 10$; 25% for $10 < E(eV/amu) < 2x10^3$; 15% for $2x10^3 < E(eV/amu) < 2x10^5$

Notes: (1) The recommended cross-section between 1 and 10 eV/amu is a smooth interpolation between cross-section data and reaction-rate measurements in the 0.1 eV/amu region [E.12].

(2) Most ion sources produce beams containing some admixture of ground-state $C^+(^2P)$ and metastable $C^+(^4P)$ ions. Typical relative abundances in ion beams are 70% ^2P and 30% ^4P [E.50]; these are probably typical of C^+ ions in a plasma. The recommended curve is believed to represent such a typical mixture of ground-state and metastable C^+ ions.

(3) Measurements in the 70-200 eV/amu energy range [E.50] with controlled C^+ initial-state distributions give capture cross sections of ~ $7x10^{-17}$ cm^2 for $C^+(^2P)$ and ~ $8x10^{-16}$ cm^2 for $C^+(^4P)$.

(4) The low-energy maximum in the cross section near 25 eV/amu is attributed to electron capture by C^+ from H_2 resulting in dissociation (dissociative charge transfer) [E.2].

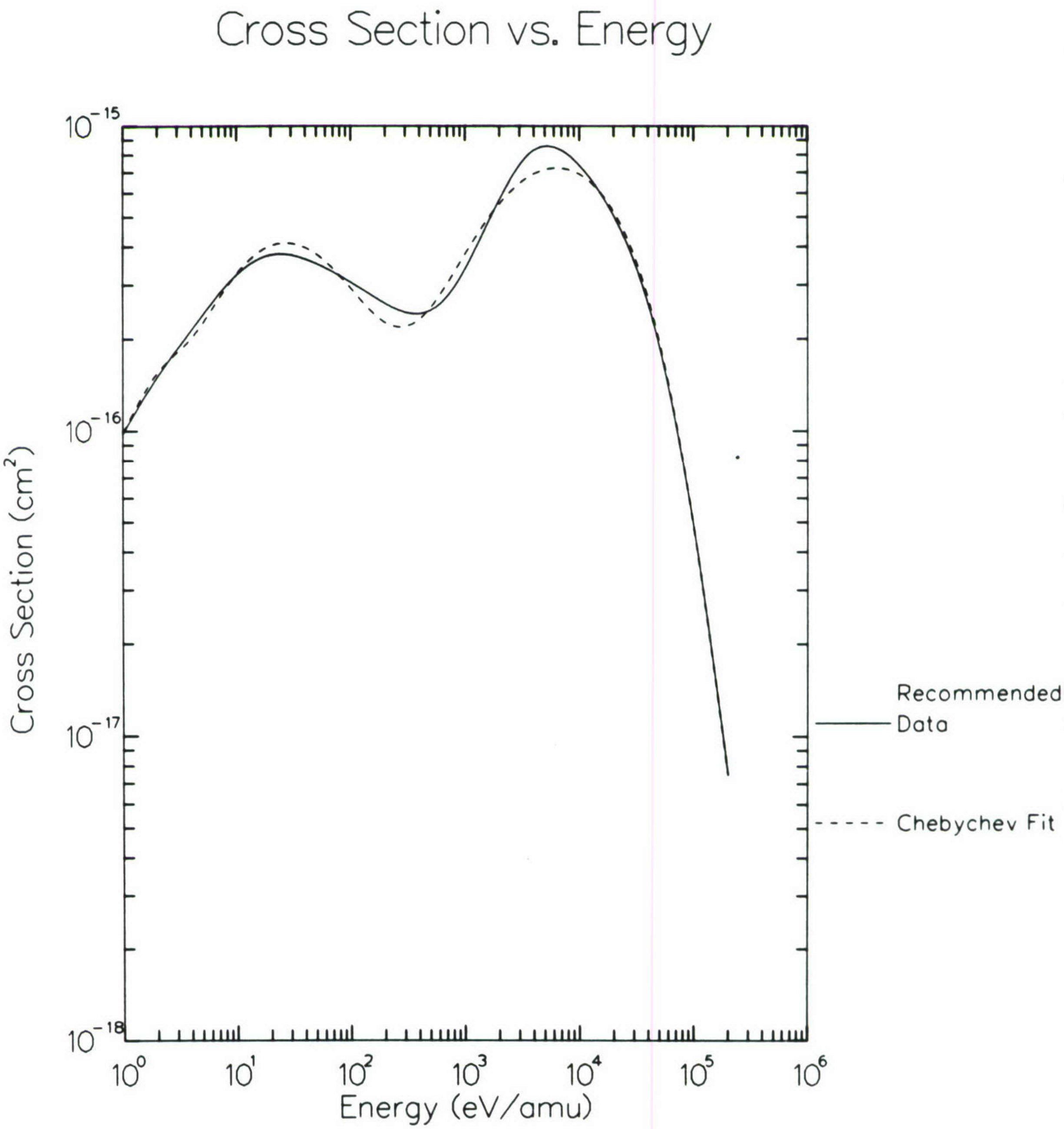
For Chebychev fits of the above cross sections it is necessary to use the following parameters.
E_{min} = 1.0E+00 eV/amu, E_{max} = 2.0E+05 eV/amu

Chebychev Fitting Parameters for Cross Sections

C1	C2	C3	C4	C5	C6	C7	C8	C9
5.388E-16	5.578E-18	-2.077E-16	-1.117E-16	-7.304E-17	5.798E-17	1.153E-16	3.242E-18	-5.168E-17

The fit represents the above cross sections with an rms deviation of 7.8%.
The maximum deviation is 13.0% at 1.0E+03 eV/amu.
See appendix for Chebychev fit details.

$C^+ + H_2 \rightarrow C + H_2^+$



Total Electron Capture Rate Coefficients for
$C^+ + H_2 \rightarrow C + H_2^+$

Maxwellian - Maxwellian Rate Coefficients (cm^3/s)

C^+ Temp. (eV)	Equal Temp.	H_2 Temp. (eV) 1.	10.	100.	1000.	5000.	10000.	20000.
1.0E+00	1.19E-10	1.19E-10	1.02E-09	3.51E-09	1.25E-08	5.49E-08	7.59E-08	8.53E-08
1.2E+00	1.46E-10	1.23E-10	1.02E-09	3.51E-09	1.25E-08	5.49E-08	7.59E-08	8.53E-08
2.4E+00	3.04E-10	1.46E-10	1.04E-09	3.52E-09	1.25E-08	5.49E-08	7.59E-08	8.53E-08
4.8E+00	6.01E-10	1.92E-10	1.07E-09	3.52E-09	1.25E-08	5.49E-08	7.59E-08	8.53E-08
8.4E+00	9.86E-10	2.60E-10	1.11E-09	3.53E-09	1.25E-08	5.49E-08	7.59E-08	8.53E-08
1.2E+01	1.30E-09	3.26E-10	1.16E-09	3.54E-09	1.25E-08	5.49E-08	7.59E-08	8.53E-08
2.4E+01	2.03E-09	5.40E-10	1.30E-09	3.56E-09	1.25E-08	5.49E-08	7.59E-08	8.53E-08
4.8E+01	2.82E-09	9.19E-10	1.55E-09	3.61E-09	1.26E-08	5.50E-08	7.59E-08	8.53E-08
8.4E+01	3.49E-09	1.37E-09	1.86E-09	3.67E-09	1.26E-08	5.50E-08	7.59E-08	8.53E-08
1.2E+02	3.94E-09	1.71E-09	2.10E-09	3.74E-09	1.27E-08	5.50E-08	7.60E-08	8.53E-08
2.4E+02	5.08E-09	2.46E-09	2.69E-09	3.94E-09	1.30E-08	5.52E-08	7.60E-08	8.53E-08
4.8E+02	7.50E-09	3.26E-09	3.38E-09	4.29E-09	1.35E-08	5.55E-08	7.61E-08	8.53E-08
8.4E+02	1.22E-08	3.95E-09	4.03E-09	4.77E-09	1.42E-08	5.59E-08	7.62E-08	8.53E-08
1.2E+03	1.76E-08	4.47E-09	4.54E-09	5.23E-09	1.50E-08	5.63E-08	7.64E-08	8.53E-08
2.4E+03	3.52E-08	6.05E-09	6.13E-09	6.93E-09	1.76E-08	5.76E-08	7.68E-08	8.53E-08
4.8E+03	5.88E-08	1.01E-08	1.02E-08	1.12E-08	2.29E-08	6.00E-08	7.77E-08	8.54E-08
8.4E+03	7.54E-08	1.76E-08	1.77E-08	1.89E-08	3.05E-08	6.32E-08	7.88E-08	8.54E-08
1.2E+04	8.23E-08	2.55E-08	2.56E-08	2.68E-08	3.74E-08	6.61E-08	7.98E-08	8.53E-08
2.0E+04	8.52E-08	4.08E-08	4.09E-08	4.18E-08	4.99E-08	7.11E-08	8.16E-08	8.52E-08

Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

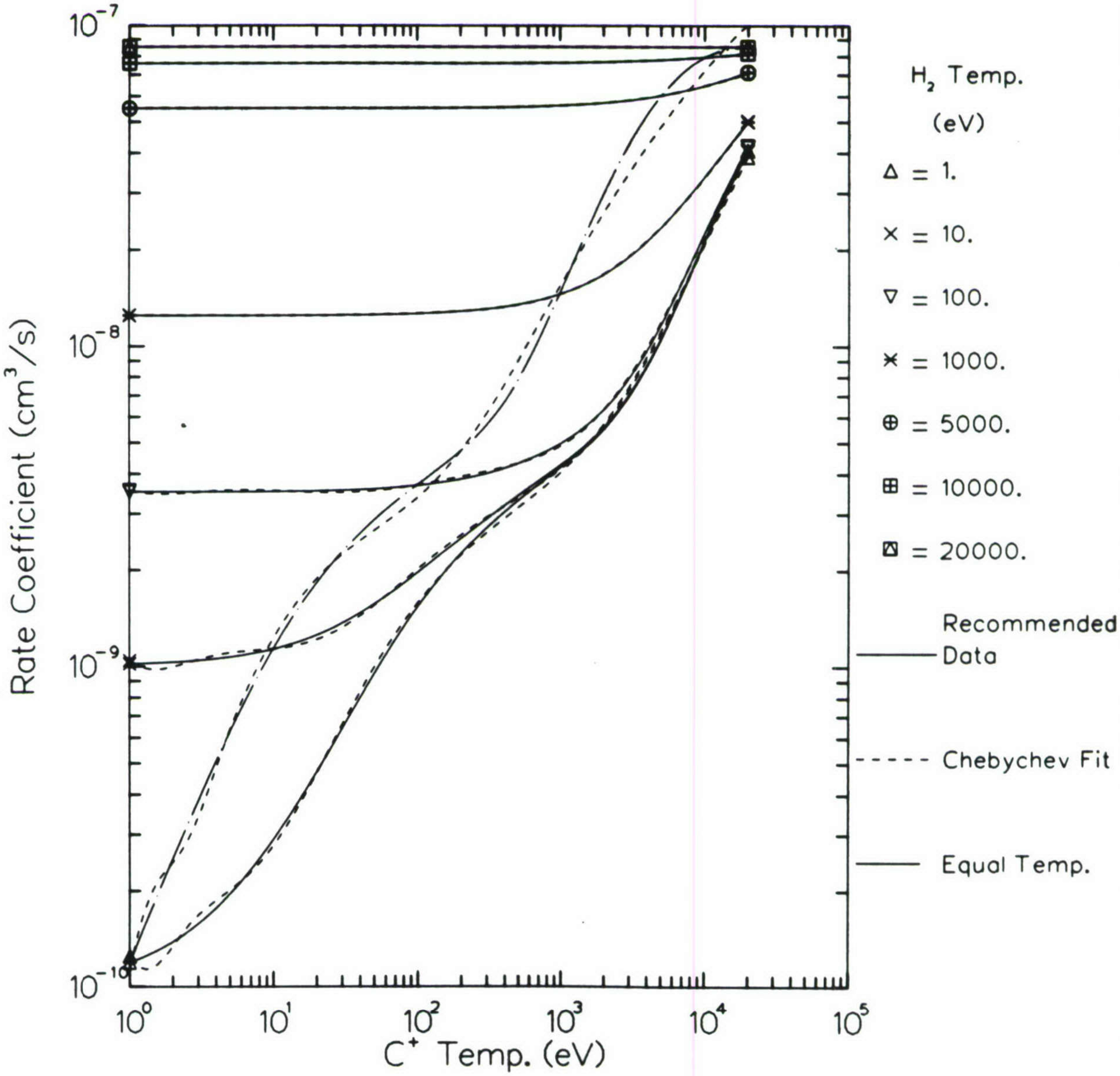
Chebychev Fitting Parameters for Rate Coefficients

H_2 Temp. (eV)	C1	C2	C3	C4	C5	C6	C7
1.	1.605E-08	1.334E-08	8.510E-09	4.844E-09	2.664E-09	1.180E-09	2.860E-10
10.	1.726E-08	1.314E-08	8.857E-09	5.256E-09	2.908E-09	1.340E-09	3.872E-10
100.	2.071E-08	1.235E-08	9.120E-09	5.659E-09	2.960E-09	1.252E-09	3.705E-10
1000.	3.967E-08	1.308E-08	9.163E-09	5.096E-09	2.219E-09	7.094E-10	1.193E-10
5000.	1.165E-07	5.856E-09	3.971E-09	2.077E-09	8.184E-10	2.206E-10	1.030E-11
10000.	1.541E-07	2.039E-09	1.391E-09	7.357E-10	2.945E-10	8.043E-11	3.729E-12
20000.	1.706E-07	4.445E-12	-1.064E-11	-2.376E-11	-2.616E-11	-1.955E-11	-1.292E-11
Equal Temp.	5.060E-08	4.136E-08	2.370E-08	9.655E-09	1.904E-09	-6.341E-10	-4.032E-10

See appendix for Chebychev fit details.

$C^+ + H_2 \rightarrow C + H_2^+$

Maxwellian – Maxwellian



Total Electron Capture Rate Coefficients for
$H_2 + C^+ \rightarrow C + H_2^+$

Beam - Maxwellian Rate Coefficients (cm^3/s)

C^+ Temp. (eV)	H_2 Energy (eV/amu) 10000.	20000.	40000.	50000.	70000.	80000.	100000.
1.0E+00	1.02E-07	9.76E-08	7.31E-08	5.90E-08	3.82E-08	3.14E-08	2.17E-08
1.2E+00	1.02E-07	9.76E-08	7.31E-08	5.90E-08	3.82E-08	3.14E-08	2.17E-08
2.4E+00	1.02E-07	9.76E-08	7.30E-08	5.90E-08	3.82E-08	3.14E-08	2.17E-08
4.8E+00	1.02E-07	9.76E-08	7.30E-08	5.90E-08	3.82E-08	3.14E-08	2.17E-08
8.4E+00	1.02E-07	9.76E-08	7.30E-08	5.90E-08	3.82E-08	3.14E-08	2.17E-08
1.2E+01	1.02E-07	9.76E-08	7.30E-08	5.90E-08	3.82E-08	3.14E-08	2.17E-08
2.4E+01	1.02E-07	9.76E-08	7.30E-08	5.90E-08	3.82E-08	3.14E-08	2.17E-08
4.8E+01	1.02E-07	9.76E-08	7.30E-08	5.90E-08	3.82E-08	3.14E-08	2.17E-08
8.4E+01	1.02E-07	9.76E-08	7.29E-08	5.90E-08	3.82E-08	3.14E-08	2.17E-08
1.2E+02	1.02E-07	9.76E-08	7.29E-08	5.90E-08	3.82E-08	3.14E-08	2.17E-08
2.4E+02	1.01E-07	9.75E-08	7.28E-08	5.90E-08	3.82E-08	3.14E-08	2.17E-08
4.8E+02	1.01E-07	9.74E-08	7.27E-08	5.90E-08	3.83E-08	3.14E-08	2.17E-08
8.4E+02	1.01E-07	9.73E-08	7.26E-08	5.89E-08	3.83E-08	3.14E-08	2.17E-08
1.2E+03	1.01E-07	9.72E-08	7.25E-08	5.89E-08	3.83E-08	3.14E-08	2.17E-08
2.4E+03	1.01E-07	9.68E-08	7.22E-08	5.89E-08	3.83E-08	3.14E-08	2.17E-08
4.8E+03	1.00E-07	9.63E-08	7.16E-08	5.86E-08	3.84E-08	3.15E-08	2.18E-08
8.4E+03	9.89E-08	9.55E-08	7.10E-08	5.84E-08	3.84E-08	3.16E-08	2.18E-08
1.2E+04	9.79E-08	9.45E-08	7.04E-08	5.81E-08	3.85E-08	3.16E-08	2.19E-08
2.0E+04	9.57E-08	9.28E-08	6.93E-08	5.75E-08	3.86E-08	3.18E-08	2.20E-08

Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

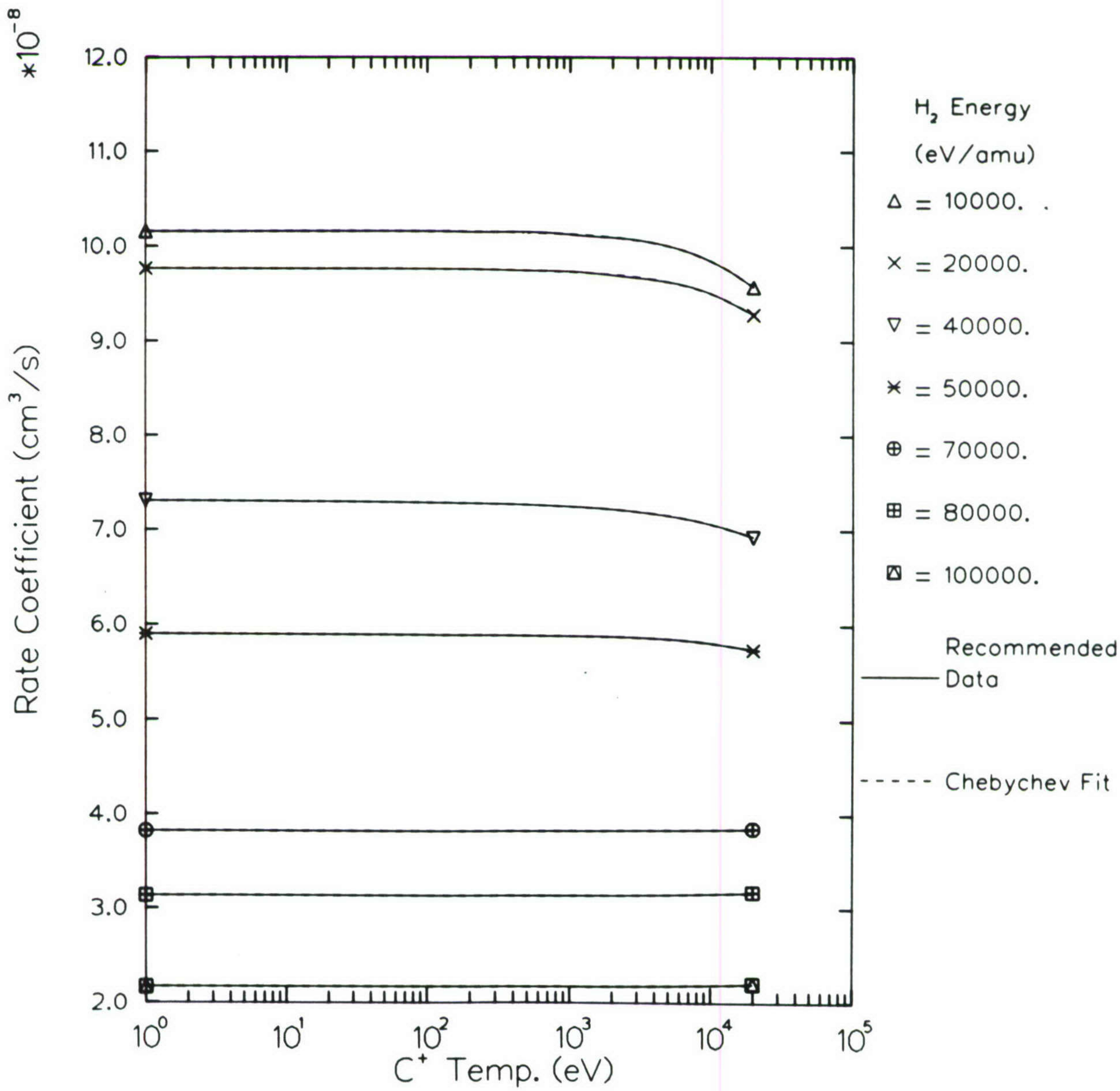
Chebychev Fitting Parameters for Rate Coefficients

H_2 Energy (eV/amu)	C1	C2	C3	C4	C5	C6	C7
10000.	2.009E-07	-1.971E-09	-1.404E-09	-7.949E-10	-3.684E-10	-1.432E-10	-4.191E-11
20000.	1.934E-07	-1.662E-09	-1.123E-09	-6.217E-10	-2.932E-10	-1.215E-10	-4.786E-11
40000.	1.444E-07	-1.425E-09	-8.402E-10	-3.937E-10	-1.537E-10	-5.014E-11	-1.423E-11
50000.	1.174E-07	-4.879E-10	-3.554E-10	-2.152E-10	-1.104E-10	-4.785E-11	-1.596E-11
70000.	7.663E-08	1.471E-10	8.111E-11	3.236E-11	8.579E-12	5.261E-13	-1.409E-12
80000.	6.288E-08	1.464E-10	1.041E-10	5.942E-11	2.714E-11	9.859E-12	3.000E-12
100000.	4.350E-08	1.018E-10	8.177E-11	5.363E-11	2.892E-11	1.277E-11	4.912E-12

See appendix for Chebychev fit details.

$H_2 + C^+ \rightarrow C + H_2^+$

Beam – Maxwellian



Total Electron Capture Cross Sections for
$C^{2+} + H_2 \rightarrow C^+ + H_2^+$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
4.0E+01	8.79E+06	3.69E-16
7.0E+01	1.16E+07	4.61E-16
1.0E+02	1.39E+07	5.28E-16
2.0E+02	1.96E+07	6.45E-16
4.0E+02	2.78E+07	7.71E-16
7.0E+02	3.68E+07	8.71E-16
1.0E+03	4.39E+07	9.32E-16
1.7E+03	5.66E+07	1.02E-15
2.0E+03	6.21E+07	1.05E-15
4.0E+03	8.79E+07	1.09E-15
7.0E+03	1.16E+08	1.03E-15
1.0E+04	1.39E+08	9.49E-16
2.0E+04	1.96E+08	7.72E-16
4.0E+04	2.78E+08	5.32E-16
7.0E+04	3.68E+08	2.20E-16
1.0E+05	4.39E+08	9.79E-17
2.0E+05	6.21E+08	1.68E-17

References: E.1, E.3, E.4

Accuracy: 15% over the entire energy range

Notes: (1) In the energy region below 40 eV/amu, the cross section continues to decrease with decreasing energy.
(2) C^{2+} beams produced in plasma ion sources contain a significant fraction of metastable C^{2+} $(2s2p)^3P^0$ ions [E.4].
(3) In analogy with the C^{2+} + H charge-exchange reaction, excited ion products C^+ $(2s2p^2)$ and C^+ (2s3p) are expected to be produced in the present case for energies above ~ 10 eV/amu.

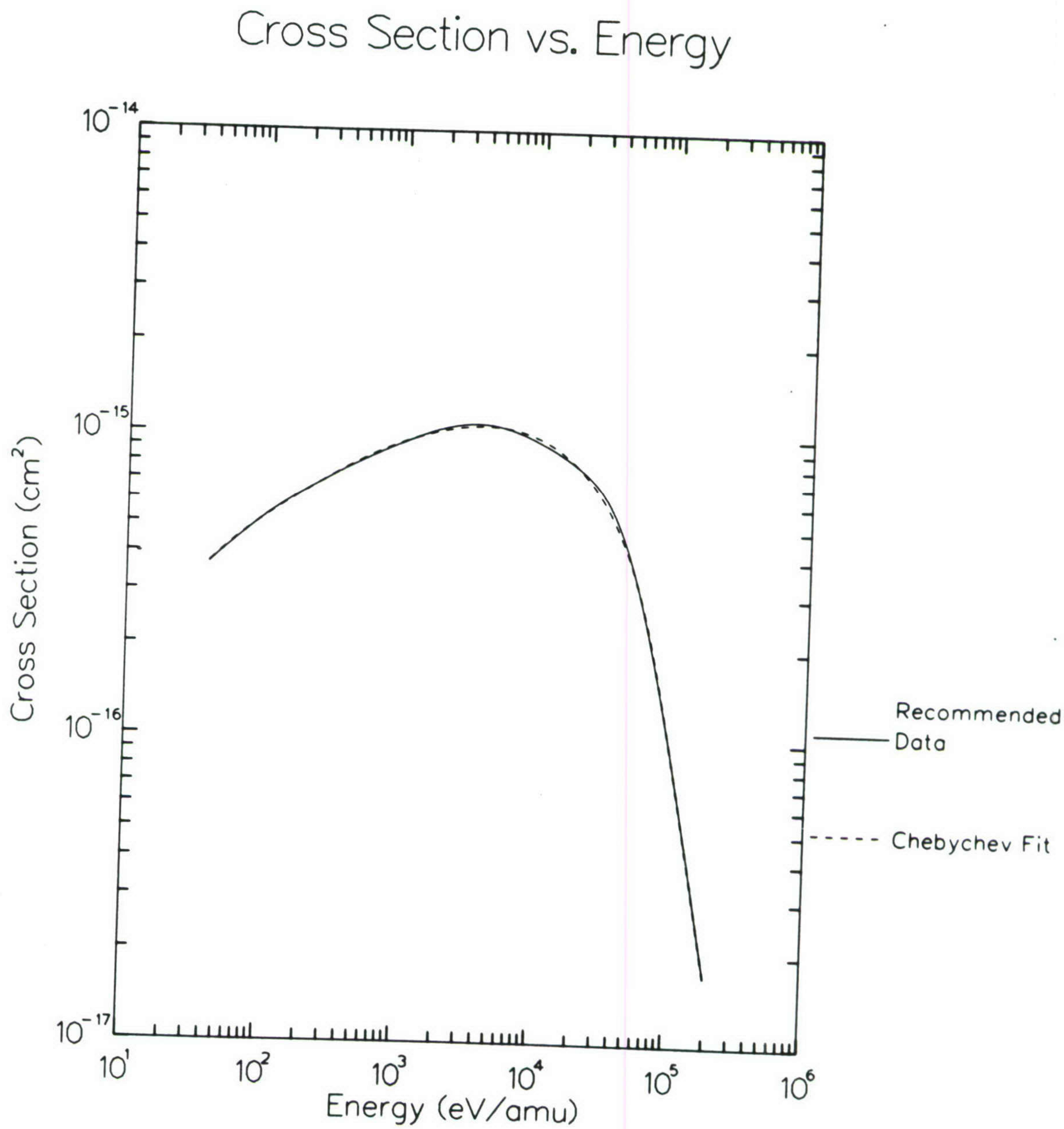
For Chebychev fits of the above cross sections it is necessary to use the following parameters.
E_{min} = 4.0E+01 eV/amu, E_{max} = 2.0E+05 eV/amu

Chebychev Fitting Parameters for Cross Sections

C1	C2	C3	C4	C5	C6	C7	C8	C9
1.080E-15	-1.798E-16	-4.441E-16	-5.043E-17	8.882E-17	5.420E-17	1.064E-17	1.704E-19	-2.717E-18

The fit represents the above cross sections with an rms deviation of 2.7%.
The maximum deviation is 5.1% at 7.0E+04 eV/amu.
See appendix for Chebychev fit details.

$$C^{2+} + H_2 \rightarrow C^{+} + H_2^{+}$$



Total Electron Capture Rate Coefficients for
$C^{2+} + H_2 \rightarrow C^+ + H_2^+$

Maxwellian - Maxwellian Rate Coefficients (cm^3/s)

C^{2+} Temp. (eV)	Equal Temp.	H_2 Temp. (eV) 1.	10.	100.	1000.	5000.	10000.	20000.
7.3E+01	4.68E-09	7.33E-10*	1.32E-09	5.90E-09	3.12E-08	8.01E-08	1.05E-07	1.25E-07
9.6E+01	5.90E-09	9.87E-10*	1.55E-09	6.07E-09	3.12E-08	8.02E-08	1.05E-07	1.25E-07
1.2E+02	7.09E-09	1.24E-09	1.79E-09	6.24E-09	3.13E-08	8.02E-08	1.05E-07	1.25E-07
2.4E+02	1.23E-08	2.42E-09	2.91E-09	7.09E-09	3.18E-08	8.04E-08	1.06E-07	1.25E-07
4.8E+02	2.05E-08	4.47E-09	4.90E-09	8.68E-09	3.26E-08	8.07E-08	1.06E-07	1.25E-07
8.4E+02	3.05E-08	7.13E-09	7.50E-09	1.09E-08	3.38E-08	8.11E-08	1.06E-07	1.25E-07
1.2E+03	3.88E-08	9.47E-09	9.80E-09	1.29E-08	3.50E-08	8.15E-08	1.06E-07	1.25E-07
2.4E+03	5.94E-08	1.61E-08	1.63E-08	1.89E-08	3.88E-08	8.29E-08	1.07E-07	1.26E-07
4.8E+03	8.43E-08	2.65E-08	2.67E-08	2.87E-08	4.56E-08	8.56E-08	1.08E-07	1.26E-07
8.4E+03	1.05E-07	3.88E-08	3.90E-08	4.05E-08	5.44E-08	8.92E-08	1.10E-07	1.27E-07
1.2E+04	1.16E-07	4.87E-08	4.88E-08	5.02E-08	6.18E-08	9.26E-08	1.11E-07	1.27E-07
2.0E+04	1.28E-07	6.52E-08	6.53E-08	6.63E-08	7.47E-08	9.89E-08	1.15E-07	1.28E-07

Accuracy: * - Possible Error Greater Than 10%
** - Possible Error Greater Than 100%

Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 7.3E+01 eV, E_{max} = 2.0E+04 eV

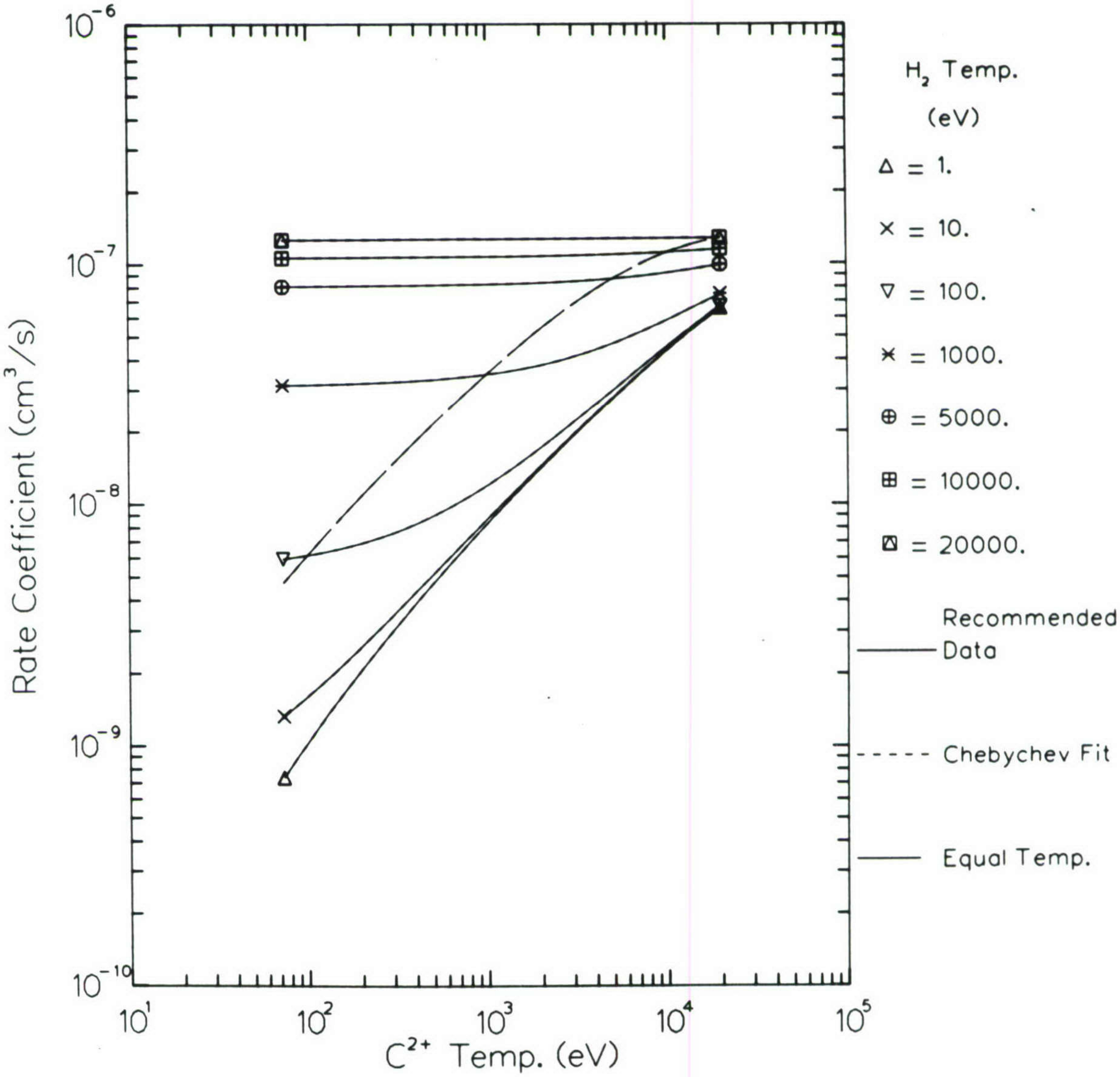
Chebychev Fitting Parameters for Rate Coefficients

H_2 Temp. (eV)	C1	C2	C3	C4	C5	C6	C7
1.	4.205E-08	2.963E-08	1.181E-08	2.764E-09	2.485E-10	-9.089E-11	-4.111E-11
10.	4.272E-08	2.938E-08	1.181E-08	2.769E-09	2.416E-10	-9.962E-11	-4.450E-11
100.	4.862E-08	2.750E-08	1.165E-08	2.847E-09	2.260E-10	-1.202E-10	-5.088E-11
1000.	8.729E-08	1.927E-08	9.018E-09	2.617E-09	3.252E-10	-9.718E-11	-5.262E-11
5000.	1.705E-07	7.975E-09	3.994E-09	1.376E-09	2.868E-10	2.568E-11	-1.998E-11
10000.	2.158E-07	3.923E-09	2.005E-09	7.115E-10	1.728E-10	2.602E-11	3.897E-12
20000.	2.519E-07	1.072E-09	5.400E-10	1.834E-10	3.828E-11	4.022E-13	-3.137E-12
Equal Temp.	1.103E-07	6.505E-08	1.357E-08	-3.044E-09	-2.577E-09	-5.001E-10	3.815E-11

See appendix for Chebychev fit details.

$C^{2+} + H_2 \rightarrow C^{+} + H_2^{+}$

Maxwellian – Maxwellian



Total Electron Capture Rate Coefficients for
$H_2 + C^{2+} \rightarrow C^+ + H_2^+$

Beam - Maxwellian Rate Coefficients (cm^3/s)

C^{2+} Temp. (eV)	H_2 Energy (eV/amu) 10000.	20000.	40000.	50000.	70000.	80000.	100000.
7.3E+01	1.32E-07	1.52E-07	1.47E-07	1.24E-07	8.09E-08	6.53E-08	4.30E-08
9.6E+01	1.32E-07	1.52E-07	1.47E-07	1.24E-07	8.09E-08	6.53E-08	4.30E-08
1.2E+02	1.32E-07	1.52E-07	1.47E-07	1.24E-07	8.09E-08	6.53E-08	4.31E-08
2.4E+02	1.32E-07	1.51E-07	1.47E-07	1.24E-07	8.09E-08	6.53E-08	4.31E-08
4.8E+02	1.32E-07	1.51E-07	1.46E-07	1.24E-07	8.09E-08	6.53E-08	4.31E-08
8.4E+02	1.32E-07	1.51E-07	1.46E-07	1.23E-07	8.09E-08	6.53E-08	4.32E-08
1.2E+03	1.32E-07	1.51E-07	1.46E-07	1.23E-07	8.09E-08	6.53E-08	4.32E-08
2.4E+03	1.32E-07	1.50E-07	1.44E-07	1.23E-07	8.09E-08	6.54E-08	4.33E-08
4.8E+03	1.32E-07	1.50E-07	1.42E-07	1.22E-07	8.10E-08	6.55E-08	4.36E-08
8.4E+03	1.32E-07	1.50E-07	1.41E-07	1.21E-07	8.09E-08	6.56E-08	4.39E-08
1.2E+04	1.32E-07	1.49E-07	1.39E-07	1.20E-07	8.09E-08	6.57E-08	4.41E-08
2.0E+04	1.32E-07	1.47E-07	1.35E-07	1.17E-07	8.07E-08	6.60E-08	4.47E-08

Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 7.3E+01 eV, E_{max} = 2.0E+04 eV

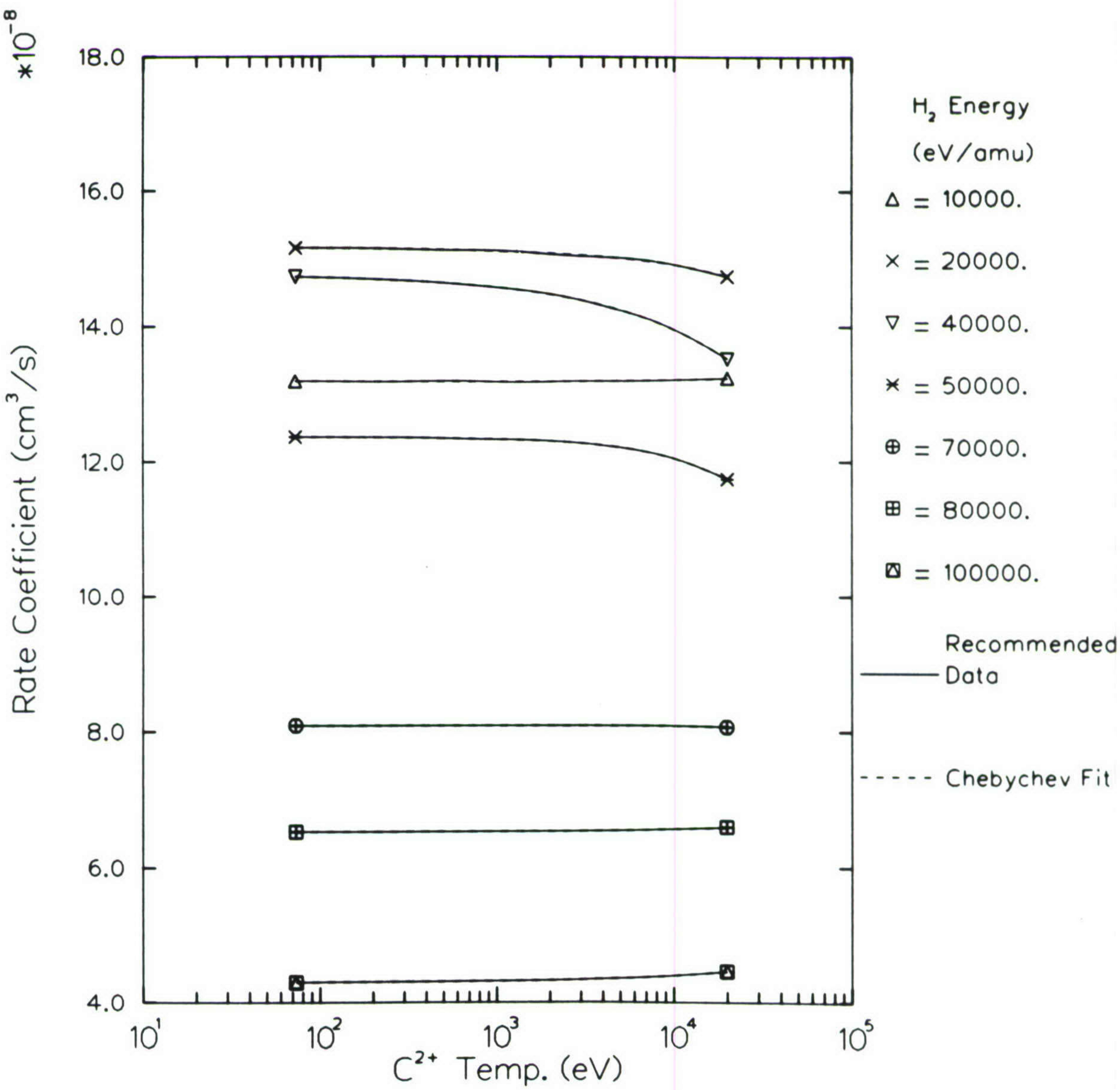
Chebychev Fitting Parameters for Rate Coefficients

H_2 Energy (eV/amu)	C1	C2	C3	C4	C5	C6	C7
10000.	2.640E-07	2.114E-10	1.329E-10	4.319E-11	7.232E-12	-8.636E-12	1.333E-12
20000.	3.007E-07	-1.774E-09	-7.574E-10	-2.721E-10	-1.008E-10	-3.557E-11	-2.987E-12
40000.	2.870E-07	-5.435E-09	-2.135E-09	-6.094E-10	-1.296E-10	-2.089E-11	-7.354E-12
50000.	2.443E-07	-2.486E-09	-1.394E-09	-5.820E-10	-1.745E-10	-1.783E-11	6.146E-12
70000.	1.617E-07	-3.325E-11	-6.735E-11	-5.088E-11	-2.528E-11	-1.185E-11	-7.650E-12
80000.	1.309E-07	2.830E-10	1.493E-10	5.688E-11	1.610E-11	2.744E-12	3.662E-12
100000.	8.700E-08	6.893E-10	3.165E-10	1.113E-10	2.975E-11	7.351E-12	5.424E-12

See appendix for Chebychev fit details.

$H_2 + C^{2+} \rightarrow C^{+} + H_2^{+}$

Beam – Maxwellian



Total Electron Capture Cross Sections for
$C^{3+} + H_2 \rightarrow C^{2+} + H_2^+$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
3.0E+01	7.61E+06	1.32E-15
4.0E+01	8.79E+06	1.11E-15
7.0E+01	1.16E+07	8.34E-16
1.0E+02	1.39E+07	7.20E-16
2.0E+02	1.96E+07	6.14E-16
4.0E+02	2.78E+07	5.59E-16
7.0E+02	3.68E+07	5.43E-16
1.0E+03	4.39E+07	5.54E-16
1.7E+03	5.66E+07	5.95E-16
2.0E+03	6.21E+07	6.05E-16
4.0E+03	8.79E+07	7.47E-16
7.0E+03	1.16E+08	1.01E-15
1.0E+04	1.39E+08	1.17E-15
2.0E+04	1.96E+08	1.47E-15
4.0E+04	2.78E+08	1.14E-15
7.0E+04	3.68E+08	5.84E-16
1.0E+05	4.39E+08	2.87E-16
1.8E+05	5.89E+08	6.18E-17

References: E.1, E.3, E.7, E.52, E.53

Accuracy: 20% for $30 \leq E(eV/amu) \leq 1.5\times10^2$; 30% for $1.5\times10^2 < E(eV/amu) < 4\times10^3$; 15% for $E \geq 4\times10^3$ eV/amu

Note: In the energy region below 30 eV/amu, the cross section continues to increase with decreasing energy due to quasi-resonant population of the 2s3l states of the C^{2+} product ion. (Cf. Note 2 of C^{3+} + H charge-exchange reaction).

For Chebychev fits of the above cross sections it is necessary to use the following parameters.
E_{min} = 3.0E+01 eV/amu, E_{max} = 1.8E+05 eV/amu

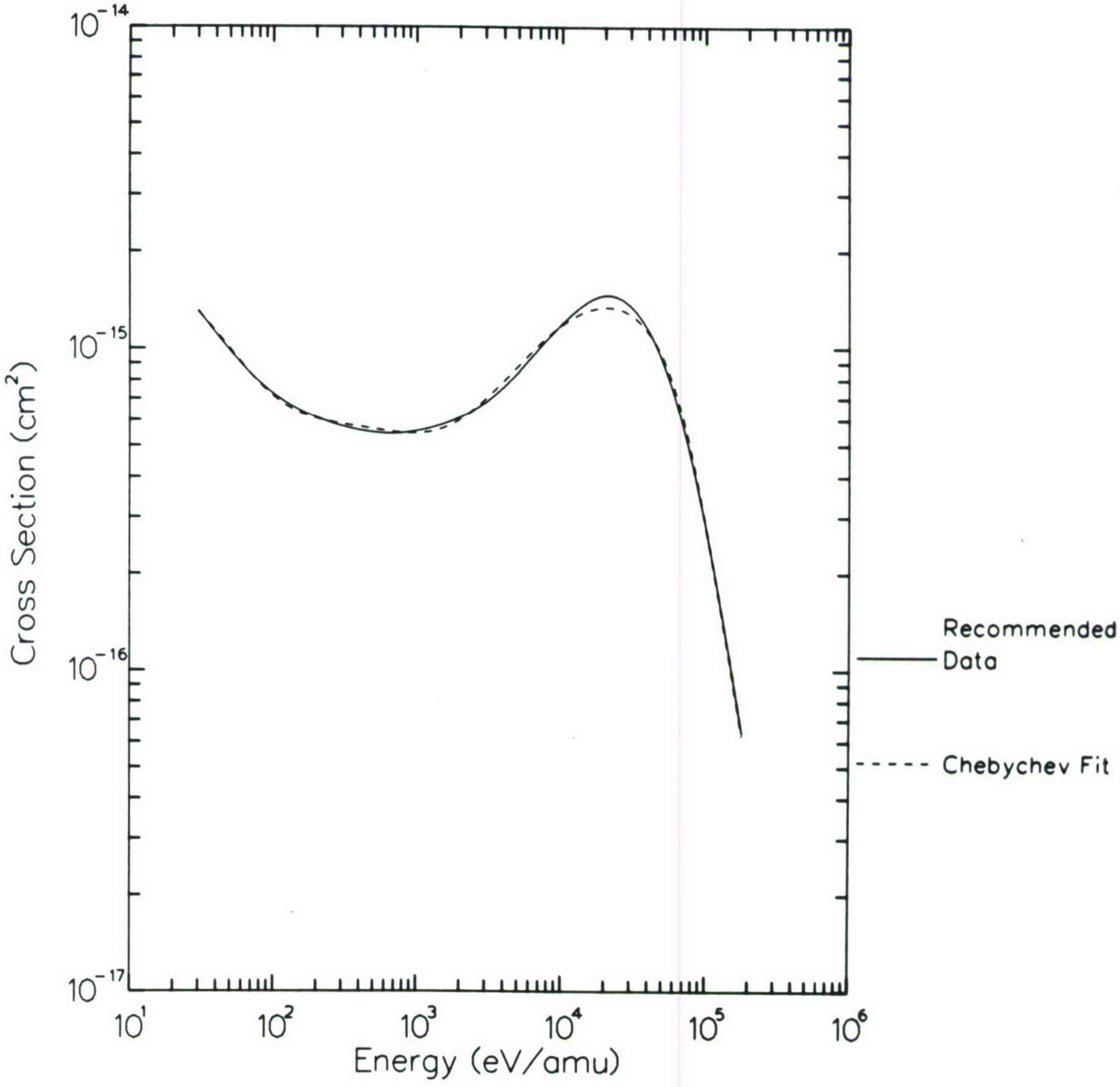
Chebychev Fitting Parameters for Cross Sections

C1	C2	C3	C4	C5	C6	C7	C8	C9
1.490E-15	-2.821E-16	-9.647E-17	-4.534E-16	-8.132E-17	5.643E-17	1.234E-16	6.012E-17	-1.004E-17

The fit represents the above cross sections with an rms deviation of 3.7%.
The maximum deviation is 7.9% at 7.0E+04 eV/amu.
See appendix for Chebychev fit details.

$C^{3+} + H_2 \rightarrow C^{2+} + H_2^{+}$

Cross Section vs. Energy



Total Electron Capture Rate Coefficients for
$C^{3+} + H_2 \rightarrow C^{2+} + H_2^{+}$

Maxwellian - Maxwellian Rate Coefficients (cm^3/s)

C^{3+} Temp. (eV)	Equal Temp.	H_2 Temp. (eV) 1.	10.	100.	1000.	5000.	10000.	20000.
5.4E+01	1.01E-08	7.76E-09*	9.52E-09*	1.03E-08	2.04E-08	6.44E-08	1.17E-07	1.87E-07
7.2E+01	1.02E-08	8.68E-09*	9.71E-09*	1.04E-08	2.05E-08	6.44E-08	1.17E-07	1.87E-07
1.2E+02	1.06E-08	9.66E-09*	9.94E-09*	1.04E-08	2.06E-08	6.45E-08	1.17E-07	1.87E-07
2.4E+02	1.22E-08	1.00E-08	1.00E-08	1.06E-08	2.08E-08	6.47E-08	1.17E-07	1.87E-07
3.6E+02	1.39E-08	1.01E-08	1.01E-08	1.08E-08	2.10E-08	6.50E-08	1.17E-07	1.87E-07
4.8E+02	1.55E-08	1.01E-08	1.02E-08	1.11E-08	2.12E-08	6.52E-08	1.18E-07	1.87E-07
8.4E+02	2.01E-08	1.06E-08	1.07E-08	1.18E-08	2.18E-08	6.59E-08	1.18E-07	1.88E-07
1.2E+03	2.46E-08	1.13E-08	1.14E-08	1.25E-08	2.25E-08	6.65E-08	1.19E-07	1.88E-07
2.4E+03	3.96E-08	1.37E-08	1.38E-08	1.48E-08	2.46E-08	6.88E-08	1.21E-07	1.89E-07
4.8E+03	7.10E-08	1.82E-08	1.83E-08	1.93E-08	2.88E-08	7.33E-08	1.24E-07	1.91E-07
8.4E+03	1.15E-07	2.46E-08	2.47E-08	2.56E-08	3.52E-08	7.99E-08	1.30E-07	1.93E-07
1.2E+04	1.51E-07	3.09E-08	3.10E-08	3.20E-08	4.18E-08	8.64E-08	1.35E-07	1.96E-07
2.0E+04	2.01E-07	4.53E-08	4.54E-08	4.65E-08	5.66E-08	1.00E-07	1.45E-07	2.01E-07

Accuracy: * - Possible Error Greater Than 10%
** - Possible Error Greater Than 100%

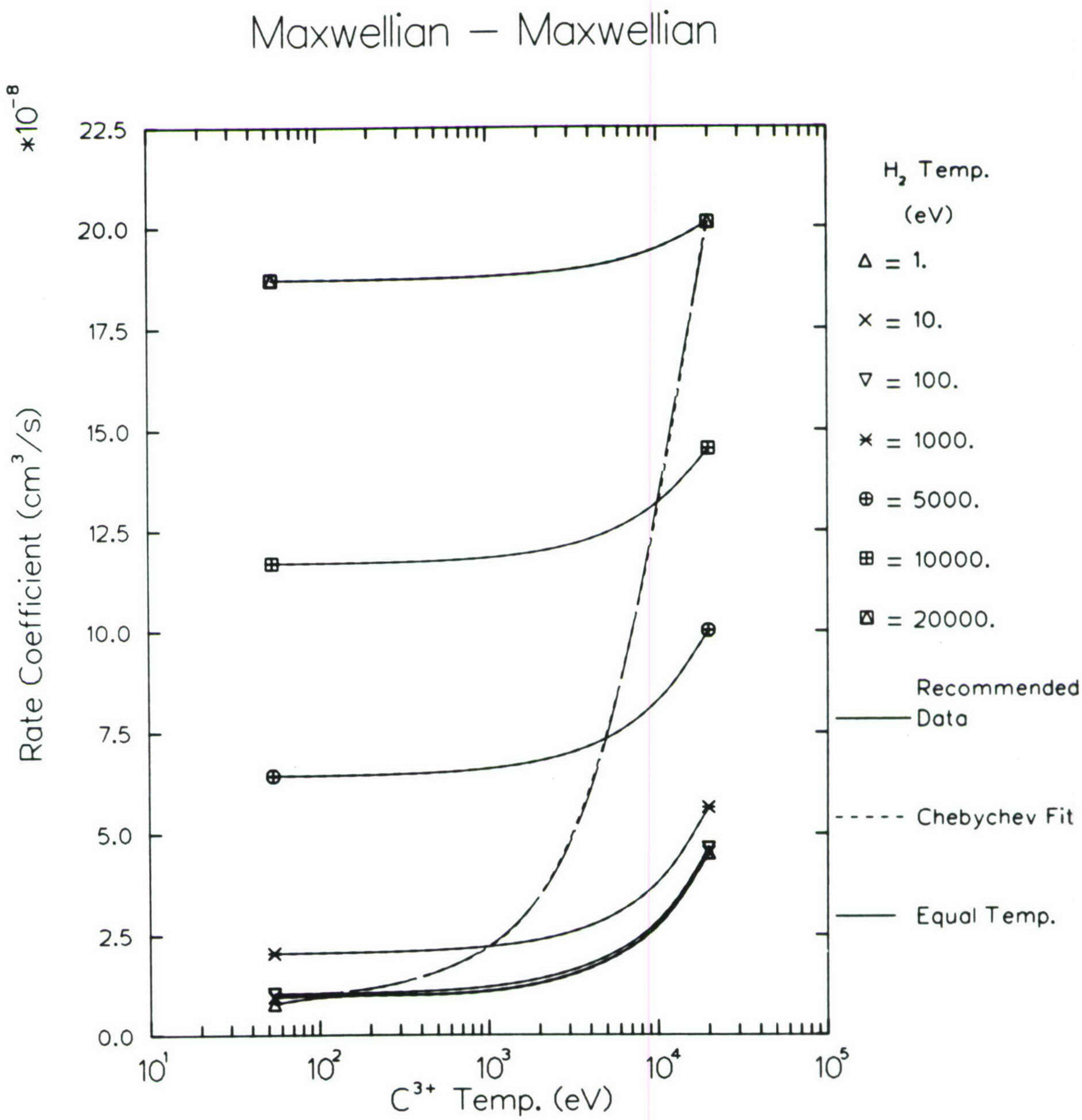
Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 5.4E+01 eV, E_{max} = 2.0E+04 eV

Chebychev Fitting Parameters for Rate Coefficients

H_2 Temp. (eV)	C1	C2	C3	C4	C5	C6	C7
1.	3.590E-08	1.462E-08	7.630E-09	3.696E-09	8.127E-10	4.547E-10	1.415E-10
10.	3.659E-08	1.415E-08	8.038E-09	3.394E-09	9.850E-10	3.890E-10	1.433E-10
100.	3.830E-08	1.436E-08	7.991E-09	3.296E-09	1.120E-09	3.669E-10	1.106E-10
1000.	5.823E-08	1.418E-08	8.075E-09	3.511E-09	1.239E-09	3.700E-10	8.868E-11
5000.	1.465E-07	1.440E-08	8.015E-09	3.304E-09	1.048E-09	2.554E-10	4.309E-11
10000.	2.482E-07	1.156E-08	6.338E-09	2.537E-09	7.618E-10	1.658E-10	2.043E-11
20000.	3.812E-07	5.759E-09	3.127E-09	1.226E-09	3.525E-10	6.876E-11	4.889E-12
Equal Temp.	1.266E-07	8.471E-08	4.293E-08	1.331E-08	1.108E-09	-1.567E-09	-8.409E-10

See appendix for Chebychev fit details.

$C^{3+} + H_2 \rightarrow C^{2+} + H_2^+$



Total Electron Capture Rate Coefficients for
$H_2 + C^{3+} \rightarrow C^{2+} + H_2^+$

Beam - Maxwellian Rate Coefficients (cm^3/s)

C^{3+} Temp. (eV)	H_2 Energy (eV/amu) 10000.	20000.	40000.	50000.	70000.	80000.	100000.
5.4E+01	1.63E-07	2.88E-07	3.16E-07	2.85E-07	2.15E-07	1.80E-07	1.26E-07
7.2E+01	1.63E-07	2.88E-07	3.16E-07	2.85E-07	2.14E-07	1.80E-07	1.26E-07
1.2E+02	1.63E-07	2.88E-07	3.16E-07	2.85E-07	2.14E-07	1.80E-07	1.26E-07
2.4E+02	1.63E-07	2.87E-07	3.16E-07	2.85E-07	2.14E-07	1.80E-07	1.26E-07
3.6E+02	1.63E-07	2.87E-07	3.16E-07	2.85E-07	2.14E-07	1.80E-07	1.26E-07
4.8E+02	1.63E-07	2.86E-07	3.16E-07	2.85E-07	2.14E-07	1.80E-07	1.26E-07
8.4E+02	1.64E-07	2.86E-07	3.15E-07	2.84E-07	2.14E-07	1.80E-07	1.26E-07
1.2E+03	1.64E-07	2.86E-07	3.15E-07	2.84E-07	2.14E-07	1.80E-07	1.26E-07
2.4E+03	1.66E-07	2.84E-07	3.13E-07	2.84E-07	2.13E-07	1.80E-07	1.26E-07
4.8E+03	1.69E-07	2.82E-07	3.11E-07	2.82E-07	2.13E-07	1.80E-07	1.27E-07
8.4E+03	1.74E-07	2.81E-07	3.08E-07	2.80E-07	2.11E-07	1.79E-07	1.27E-07
1.2E+04	1.78E-07	2.78E-07	3.04E-07	2.77E-07	2.10E-07	1.79E-07	1.27E-07
2.0E+04	1.87E-07	2.76E-07	2.98E-07	2.72E-07	2.08E-07	1.78E-07	1.28E-07

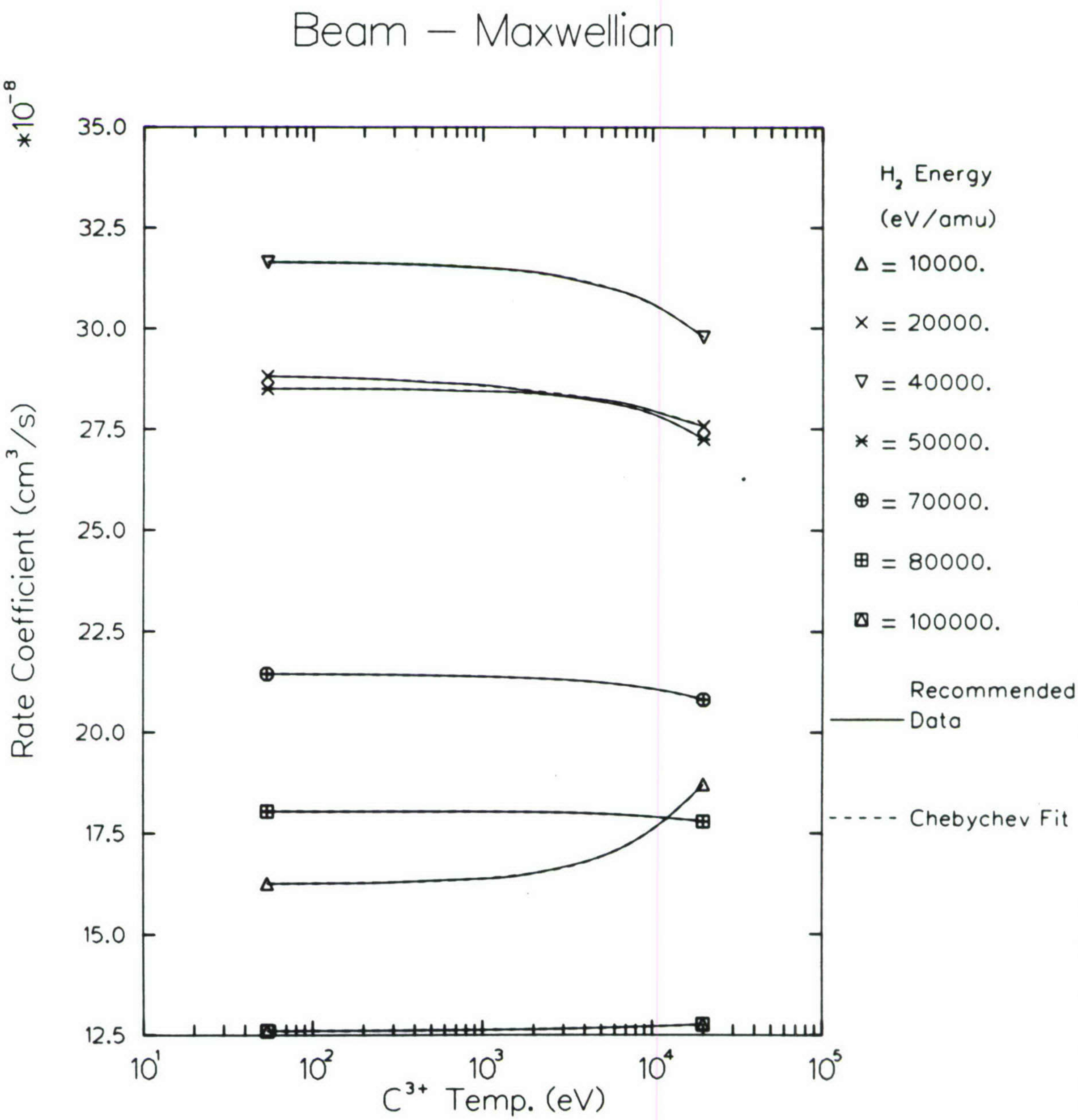
Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 5.4E+01 eV, E_{max} = 2.0E+04 eV

Chebychev Fitting Parameters for Rate Coefficients

H_2 Energy (eV/amu)	C1	C2	C3	C4	C5	C6	C7
10000.	3.377E-07	1.008E-08	5.524E-09	2.147E-09	5.525E-10	3.216E-11	-3.445E-11
20000.	5.677E-07	-5.747E-09	-1.888E-09	-4.548E-10	-1.256E-10	-3.867E-11	8.834E-12
40000.	6.228E-07	-7.841E-09	-3.900E-09	-1.436E-09	-4.032E-10	-8.864E-11	-2.318E-11
50000.	5.638E-07	-4.998E-09	-2.787E-09	-1.167E-09	-3.932E-10	-9.070E-11	-9.274E-12
70000.	4.256E-07	-2.638E-09	-1.271E-09	-4.740E-10	-1.422E-10	-3.672E-11	-1.618E-11
80000.	3.597E-07	-1.001E-09	-6.009E-10	-2.644E-10	-7.471E-11	-9.065E-12	1.238E-11
100000.	2.531E-07	7.006E-10	3.072E-10	9.697E-11	1.705E-11	-6.918E-13	7.580E-12

See appendix for Chebychev fit details.

$H_2 + C^{3+} \rightarrow C^{2+} + H_2^+$



Total Electron Capture Cross Sections for
$C^{4+} + H_2 \rightarrow C^{3+} + H_2^+$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
1.0E+00	1.39E+06	2.23E-15
2.0E+00	1.96E+06	2.86E-15
4.0E+00	2.78E+06	3.34E-15
7.0E+00	3.68E+06	3.88E-15
1.0E+01	4.39E+06	4.11E-15
2.0E+01	6.21E+06	4.55E-15
4.0E+01	8.79E+06	4.60E-15
7.0E+01	1.16E+07	4.56E-15
1.0E+02	1.39E+07	4.34E-15
2.0E+02	1.96E+07	3.92E-15
4.0E+02	2.78E+07	3.46E-15
7.0E+02	3.68E+07	3.04E-15
1.0E+03	4.39E+07	2.78E-15
1.7E+03	5.66E+07	2.48E-15
2.0E+03	6.21E+07	2.53E-15
4.0E+03	8.79E+07	2.38E-15
7.0E+03	1.16E+08	2.29E-15
1.0E+04	1.39E+08	2.18E-15
2.0E+04	1.96E+08	1.93E-15
4.0E+04	2.78E+08	1.53E-15
7.0E+04	3.68E+08	9.52E-16
1.0E+05	4.39E+08	5.50E-16
2.0E+05	6.21E+08	7.30E-17
4.0E+05	8.78E+08	2.47E-18

References: E.1, E.3, E.8, E.9, E.19, E.31, E.52, E.53, E.54, E.55, T.15

Accuracy: 40% for $1 \leq E(eV/amu) < 30$; 20% for $30 \leq E(eV/amu) < 1x10^4$; 15% for $1x10^4 < E(eV/amu) \leq 2x10^5$; 40% for $E > 2x10^5$ eV/amu

Notes: (1) There is both theoretical [T.15] and experimental [E.55] evidence that in the region below ~ $7x10^2$ eV/amu the n=3 shell is dominantly populated in the process, with capture to the 3s final state being favored. In the region around $6x10^3$ eV/amu, however, the 3d level becomes preferentially populated and capture to 2p and n=4 levels is also considerable [E.31].

(2) The cross section for $E > 2x10^5$ eV/amu has been obtained by using the scaling ratio for $\sigma(H_2)/\sigma(H)$ of Ref. [E.18] (see sect. 1.1.4).

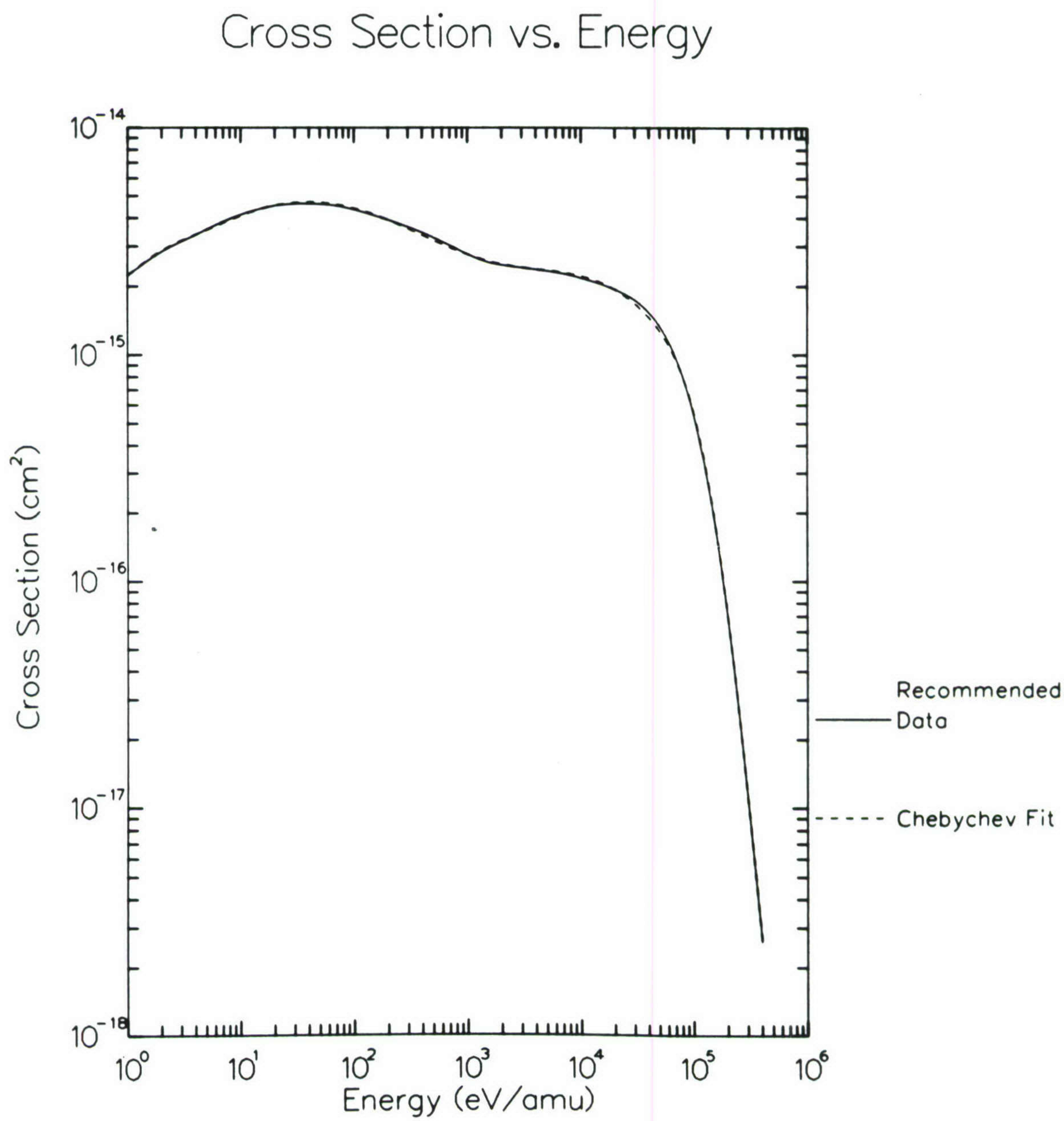
For Chebychev fits of the above cross sections it is necessary to use the following parameters.
E_{min} = 1.0E+00 eV/amu, E_{max} = 4.0E+05 eV/amu

Chebychev Fitting Parameters for Cross Sections

C1	C2	C3	C4	C5	C6	C7	C8	C9
4.665E-15	-1.615E-15	-1.226E-15	4.849E-16	-1.669E-16	-8.785E-17	2.666E-16	1.070E-16	-9.219E-17

The fit represents the above cross sections with an rms deviation of 2.2%.
The maximum deviation is 5.4% at 1.0E+05 eV/amu.
See appendix for Chebychev fit details.

$C^{4+} + H_2 \rightarrow C^{3+} + H_2^+$



Total Electron Capture Rate Coefficients for
$C^{4+} + H_2 \rightarrow C^{3+} + H_2^+$

Maxwellian - Maxwellian Rate Coefficients (cm^3/s)

C^{4+} Temp. (eV)	Equal Temp.	H_2 Temp. (eV) 1.	10.	100.	1000.	5000.	10000.	20000.
1.2E+01	1.68E-08	5.14E-09*	1.52E-08	4.84E-08	1.06E-07	1.90E-07	2.47E-07	3.08E-07
2.4E+01	2.57E-08	8.01E-09	1.68E-08	4.87E-08	1.06E-07	1.90E-07	2.47E-07	3.08E-07
4.8E+01	3.69E-08	1.25E-08	1.97E-08	4.95E-08	1.06E-07	1.90E-07	2.47E-07	3.08E-07
8.4E+01	4.75E-08	1.76E-08	2.35E-08	5.06E-08	1.06E-07	1.90E-07	2.47E-07	3.08E-07
1.2E+02	5.50E-08	2.17E-08	2.67E-08	5.17E-08	1.07E-07	1.90E-07	2.47E-07	3.08E-07
2.4E+02	7.09E-08	3.16E-08	3.49E-08	5.50E-08	1.07E-07	1.91E-07	2.47E-07	3.08E-07
4.8E+02	8.87E-08	4.38E-08	4.58E-08	6.05E-08	1.09E-07	1.91E-07	2.47E-07	3.08E-07
8.4E+02	1.05E-07	5.51E-08	5.65E-08	6.72E-08	1.10E-07	1.92E-07	2.48E-07	3.08E-07
1.2E+03	1.18E-07	6.31E-08	6.41E-08	7.26E-08	1.12E-07	1.93E-07	2.49E-07	3.09E-07
2.4E+03	1.52E-07	7.99E-08	8.04E-08	8.56E-08	1.18E-07	1.96E-07	2.50E-07	3.09E-07
4.8E+03	1.99E-07	9.89E-08	9.92E-08	1.03E-07	1.29E-07	2.01E-07	2.54E-07	3.11E-07
8.4E+03	2.45E-07	1.18E-07	1.19E-07	1.21E-07	1.43E-07	2.09E-07	2.58E-07	3.13E-07
1.2E+04	2.77E-07	1.34E-07	1.34E-07	1.36E-07	1.56E-07	2.16E-07	2.63E-07	3.15E-07
2.0E+04	3.19E-07	1.62E-07	1.62E-07	1.64E-07	1.80E-07	2.31E-07	2.72E-07	3.20E-07

Accuracy: * - Possible Error Greater Than 10%
** - Possible Error Greater Than 100%

Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.2E+01 eV, E_{max} = 2.0E+04 eV

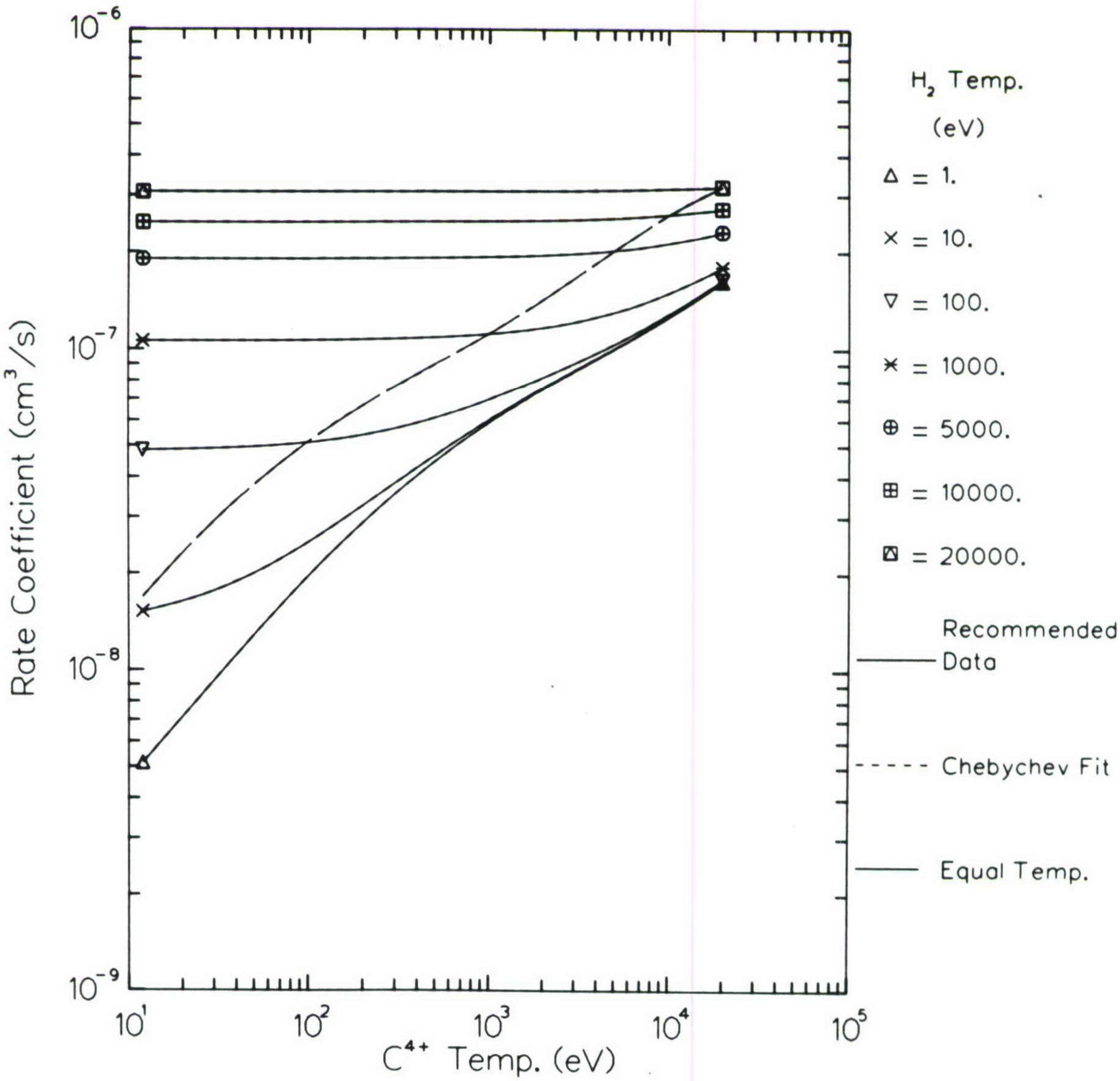
Chebychev Fitting Parameters for Rate Coefficients

H_2 Temp. (eV)	C1	C2	C3	C4	C5	C6	C7
1.	1.242E-07	7.458E-08	1.953E-08	2.859E-09	1.847E-09	1.113E-09	2.383E-10
10.	1.319E-07	6.940E-08	2.102E-08	3.090E-09	1.571E-09	1.140E-09	2.957E-10
100.	1.647E-07	5.157E-08	2.238E-08	5.630E-09	1.165E-09	6.652E-10	3.371E-10
1000.	2.473E-07	2.930E-08	1.712E-08	7.160E-09	2.077E-09	3.279E-10	-3.691E-11
5000.	3.986E-07	1.560E-08	9.538E-09	4.369E-09	1.509E-09	3.719E-10	4.651E-11
10000.	5.051E-07	9.749E-09	6.021E-09	2.819E-09	1.014E-09	2.733E-10	4.704E-11
20000.	6.209E-07	4.549E-09	2.814E-09	1.321E-09	4.780E-10	1.298E-10	2.251E-11
Equal Temp.	2.572E-07	1.443E-07	4.097E-08	9.712E-09	-4.999E-11	-2.613E-09	-1.245E-09

See appendix for Chebychev fit details.

$C^{4+} + H_2 \rightarrow C^{3+} + H_2^+$

Maxwellian — Maxwellian



Total Electron Capture Rate Coefficients for
$H_2 + C^{4+} \rightarrow C^{3+} + H_2^+$

Beam - Maxwellian Rate Coefficients (cm^3/s)

C^{4+} Temp. (eV)	H_2 Energy (eV/amu) 10000.	20000.	40000.	70000.	100000.	200000.	500000.
1.2E+01	3.03E-07	3.79E-07	4.25E-07	3.50E-07	2.41E-07	4.54E-08	5.18E-10*
2.4E+01	3.03E-07	3.79E-07	4.25E-07	3.50E-07	2.41E-07	4.53E-08	5.19E-10*
4.8E+01	3.03E-07	3.79E-07	4.25E-07	3.50E-07	2.41E-07	4.53E-08	5.20E-10*
8.4E+01	3.03E-07	3.79E-07	4.24E-07	3.49E-07	2.41E-07	4.53E-08	5.21E-10*
1.2E+02	3.03E-07	3.79E-07	4.24E-07	3.49E-07	2.41E-07	4.53E-08	5.22E-10*
2.4E+02	3.03E-07	3.79E-07	4.24E-07	3.49E-07	2.41E-07	4.54E-08	5.25E-10*
4.8E+02	3.03E-07	3.78E-07	4.23E-07	3.49E-07	2.41E-07	4.54E-08	5.29E-10*
8.4E+02	3.03E-07	3.79E-07	4.22E-07	3.48E-07	2.41E-07	4.54E-08	5.34E-10*
1.2E+03	3.03E-07	3.78E-07	4.22E-07	3.48E-07	2.41E-07	4.55E-08	5.38E-10*
2.4E+03	3.04E-07	3.77E-07	4.21E-07	3.47E-07	2.40E-07	4.56E-08	5.48E-10*
4.8E+03	3.05E-07	3.78E-07	4.17E-07	3.45E-07	2.39E-07	4.59E-08	5.63E-10*
8.4E+03	3.07E-07	3.78E-07	4.15E-07	3.42E-07	2.38E-07	4.63E-08	5.80E-10*
1.2E+04	3.09E-07	3.77E-07	4.11E-07	3.40E-07	2.37E-07	4.67E-08	5.95E-10*
2.0E+04	3.13E-07	3.76E-07	4.06E-07	3.36E-07	2.35E-07	4.77E-08	6.25E-10*

Accuracy: * - Possible Error Greater Than 10%
** - Possible Error Greater Than 100%

Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.2E+01 eV, E_{max} = 2.0E+04 eV

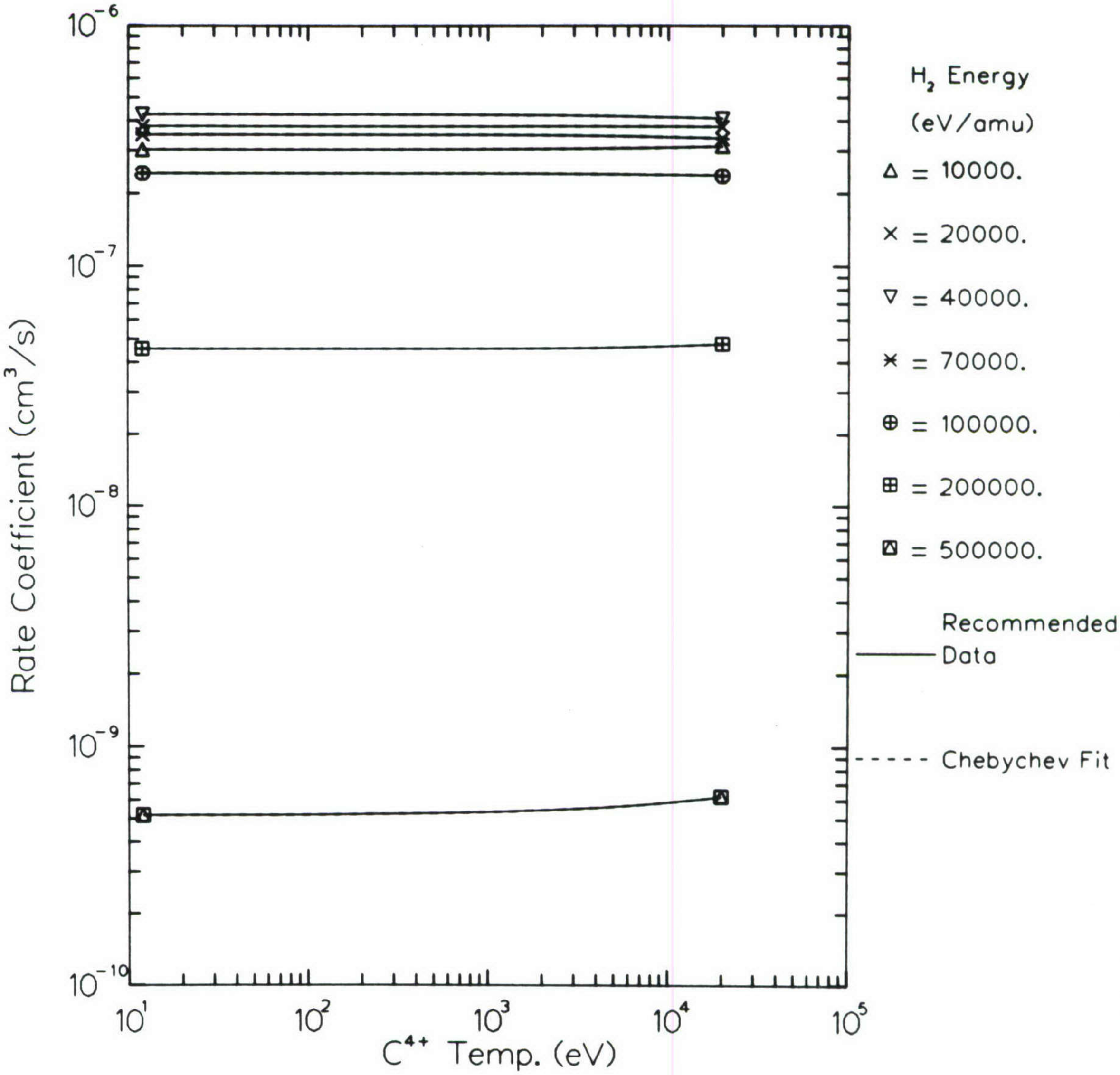
Chebychev Fitting Parameters for Rate Coefficients

H_2 Energy (eV/amu)	C1	C2	C3	C4	C5	C6	C7
10000.	6.101E-07	3.741E-09	2.467E-09	1.268E-09	4.849E-10	1.383E-10	2.193E-11
20000.	7.563E-07	-1.302E-09	-4.315E-10	-7.542E-11	-3.839E-11	-4.373E-11	-1.595E-11
40000.	8.397E-07	-7.717E-09	-3.837E-09	-1.442E-09	-4.213E-10	-8.880E-11	-1.499E-11
70000.	6.923E-07	-5.625E-09	-2.970E-09	-1.249E-09	-4.280E-10	-1.295E-10	-3.734E-11
100000.	4.796E-07	-2.565E-09	-1.290E-09	-4.798E-10	-1.693E-10	-4.455E-11	-1.636E-11
200000.	9.168E-08	8.471E-10	5.744E-10	2.730E-10	1.258E-10	2.841E-11	1.422E-11
500000.	1.096E-09	4.561E-11	2.065E-11	7.280E-12	2.266E-12	6.916E-13	2.246E-13

See appendix for Chebychev fit details.

$H_2 + C^{4+} \rightarrow C^{3+} + H_2^+$

Beam – Maxwellian



Total Electron Capture Cross Sections for
$C^{5+} + H_2 \rightarrow C^{4+} + H_2^+$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
1.0E+02	1.39E+07	2.20E-15
2.0E+02	1.96E+07	1.18E-15
4.0E+02	2.78E+07	7.87E-16
7.0E+02	3.68E+07	9.35E-16
1.0E+03	4.39E+07	1.09E-15
1.7E+03	5.66E+07	1.40E-15
2.0E+03	6.21E+07	1.61E-15
4.0E+03	8.79E+07	2.22E-15
7.0E+03	1.16E+08	2.73E-15
1.0E+04	1.39E+08	2.88E-15
2.0E+04	1.96E+08	2.74E-15
4.0E+04	2.78E+08	2.09E-15
7.0E+04	3.68E+08	1.36E-15
1.0E+05	4.39E+08	7.53E-16
2.0E+05	6.21E+08	1.11E-16
4.0E+05	8.78E+08	5.50E-18
7.0E+05	1.16E+09	4.24E-19
1.0E+06	1.39E+09	1.01E-19

References: E.3, E.7, E.8, E.9, E.56

Accuracy: 20% for $E \leq 4x10^2$ eV/amu; 40% for $4x10^2 < E(eV/amu) < 2.2x10^3$; 15% for $2.2x10^3 \leq E(eV/amu) \leq 2x10^5$; 40% for $E > 2x10^5$ eV/amu

Notes: (1) In the region $E > 2x10^5$ eV/amu the cross section has been constructed by using the scaling ratio for $\sigma(H_2)/\sigma(H)$ [E.18], normalized to the data points in the $(1.5-2)x10^5$ eV/amu region (see sect. 1.1.4).

(2) In the region below $5x10^4$ eV/amu, the capture goes dominantly to the n=3 and the n=4 shells of C^{4+}, with capture to n=4 probably dominating for $E < 3x10^2$ eV/amu.

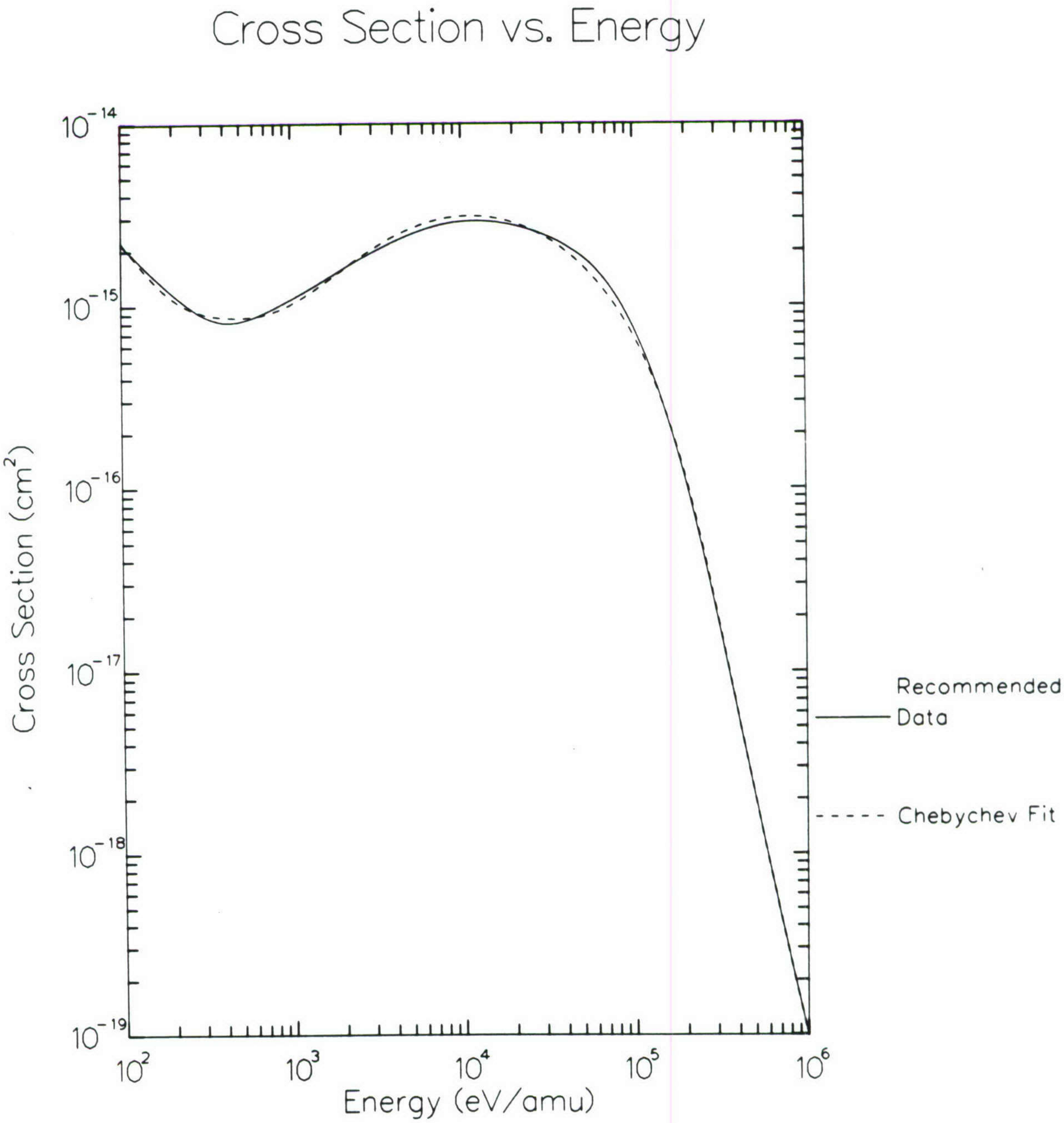
For Chebychev fits of the above cross sections it is necessary to use the following parameters.
E_{min} = 1.0E+02 eV/amu, E_{max} = 1.0E+06 eV/amu

Chebychev Fitting Parameters for Cross Sections

C1	C2	C3	C4	C5	C6	C7	C8	C9
2.338E-15	-7.537E-16	-7.396E-16	-2.666E-16	8.195E-16	-5.477E-19	-2.275E-16	-1.149E-16	1.147E-16

The fit represents the above cross sections with an rms deviation of 7.1%.
The maximum deviation is 12.4% at 4.0E+02 eV/amu.
See appendix for Chebychev fit details.

$C^{5+} + H_2 \rightarrow C^{4+} + H_2^+$



Total Electron Capture Rate Coefficients for
$C^{5+} + H_2 \rightarrow C^{4+} + H_2^+$

Maxwellian - Maxwellian Rate Coefficients (cm^3/s)

C^{5+} Temp. (eV)	Equal Temp.	H_2 Temp. (eV) 1.	10.	100.	1000.	5000.	10000.	20000.
1.2E+03	5.35E-08	1.42E-08*	1.46E-08*	1.79E-08*	4.64E-08	1.76E-07	2.84E-07	3.99E-07
2.4E+03	1.03E-07	2.09E-08*	2.12E-08*	2.38E-08*	5.35E-08	1.81E-07	2.88E-07	4.00E-07
4.8E+03	1.87E-07	3.29E-08	3.32E-08	3.62E-08	6.77E-08	1.92E-07	2.94E-07	4.03E-07
8.4E+03	2.77E-07	5.35E-08	5.38E-08	5.70E-08	8.89E-08	2.07E-07	3.04E-07	4.07E-07
1.2E+04	3.39E-07	7.49E-08	7.52E-08	7.84E-08	1.09E-07	2.21E-07	3.12E-07	4.11E-07
2.0E+04	4.19E-07	1.20E-07	1.20E-07	1.23E-07	1.51E-07	2.49E-07	3.31E-07	4.19E-07

Accuracy: * - Possible Error Greater Than 10%
** - Possible Error Greater Than 100%

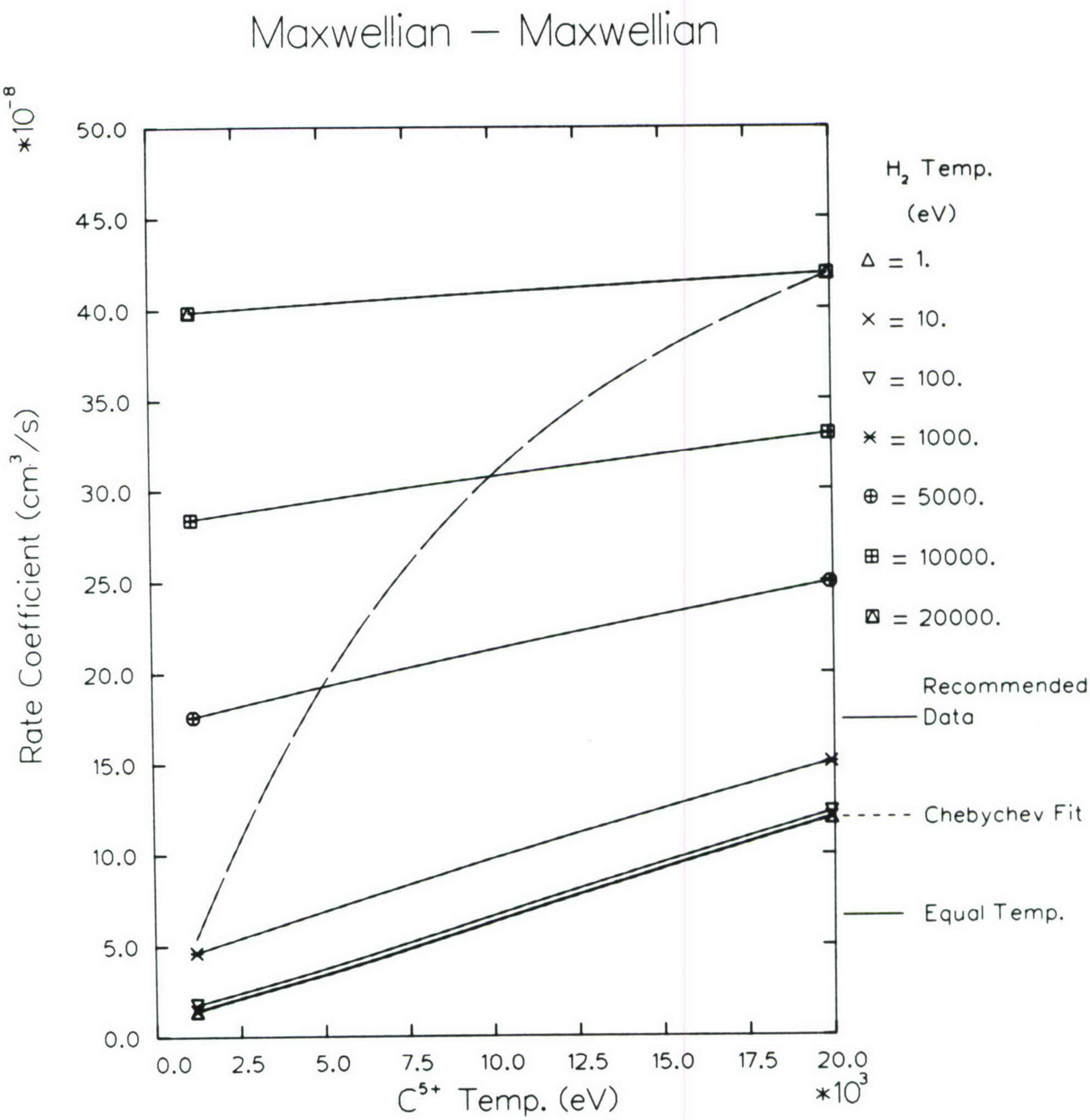
Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.2E+03 eV, E_{max} = 2.0E+04 eV

Chebychev Fitting Parameters for Rate Coefficients

H_2 Temp. (eV)	C1	C2	C3	C4	C5	C6	C7
1.	1.002E-07	4.903E-08	1.683E-08	3.911E-09	1.235E-10	-4.155E-11	
10.	1.008E-07	4.901E-08	1.686E-08	3.868E-09	1.361E-10	-4.099E-11	
100.	1.068E-07	4.911E-08	1.695E-08	3.566E-09	1.962E-10	-7.452E-11	
1000.	1.664E-07	4.947E-08	1.520E-08	2.841E-09	2.643E-10	-4.061E-11	
5000.	4.046E-07	3.498E-08	1.016E-08	1.785E-09	1.965E-10	-1.092E-10	
10000.	6.016E-07	2.199E-08	6.464E-09	1.251E-09	1.260E-10	2.670E-11	
20000.	8.117E-07	9.723E-09	2.902E-09	5.409E-10	5.919E-11	-1.788E-12	
Equal Temp.	4.299E-07	1.891E-07	2.328E-08	-6.398E-09	-2.209E-09	-1.177E-10	

See appendix for Chebychev fit details.

$C^{5+} + H_2 \rightarrow C^{4+} + H_2^+$



Total Electron Capture Rate Coefficients for
$H_2 + C^{5+} \rightarrow C^{4+} + H_2^+$

Beam - Maxwellian Rate Coefficients (cm^3/s)

C^{5+} Temp. (eV)	H_2 Energy (eV/amu) 10000.	20000.	40000.	70000.	100000.	200000.	500000.
1.2E+03	4.00E-07	5.37E-07	5.78E-07	4.95E-07	3.30E-07	6.91E-08	1.98E-09
2.4E+03	4.01E-07	5.36E-07	5.78E-07	4.93E-07	3.30E-07	6.92E-08	1.98E-09
4.8E+03	4.03E-07	5.35E-07	5.75E-07	4.89E-07	3.30E-07	6.96E-08	1.99E-09
8.4E+03	4.05E-07	5.33E-07	5.73E-07	4.84E-07	3.29E-07	7.01E-08	2.01E-09
1.2E+04	4.08E-07	5.30E-07	5.69E-07	4.80E-07	3.28E-07	7.06E-08	2.03E-09
2.0E+04	4.14E-07	5.27E-07	5.64E-07	4.72E-07	3.27E-07	7.18E-08	2.07E-09

Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.2E+03 eV, E_{max} = 2.0E+04 eV

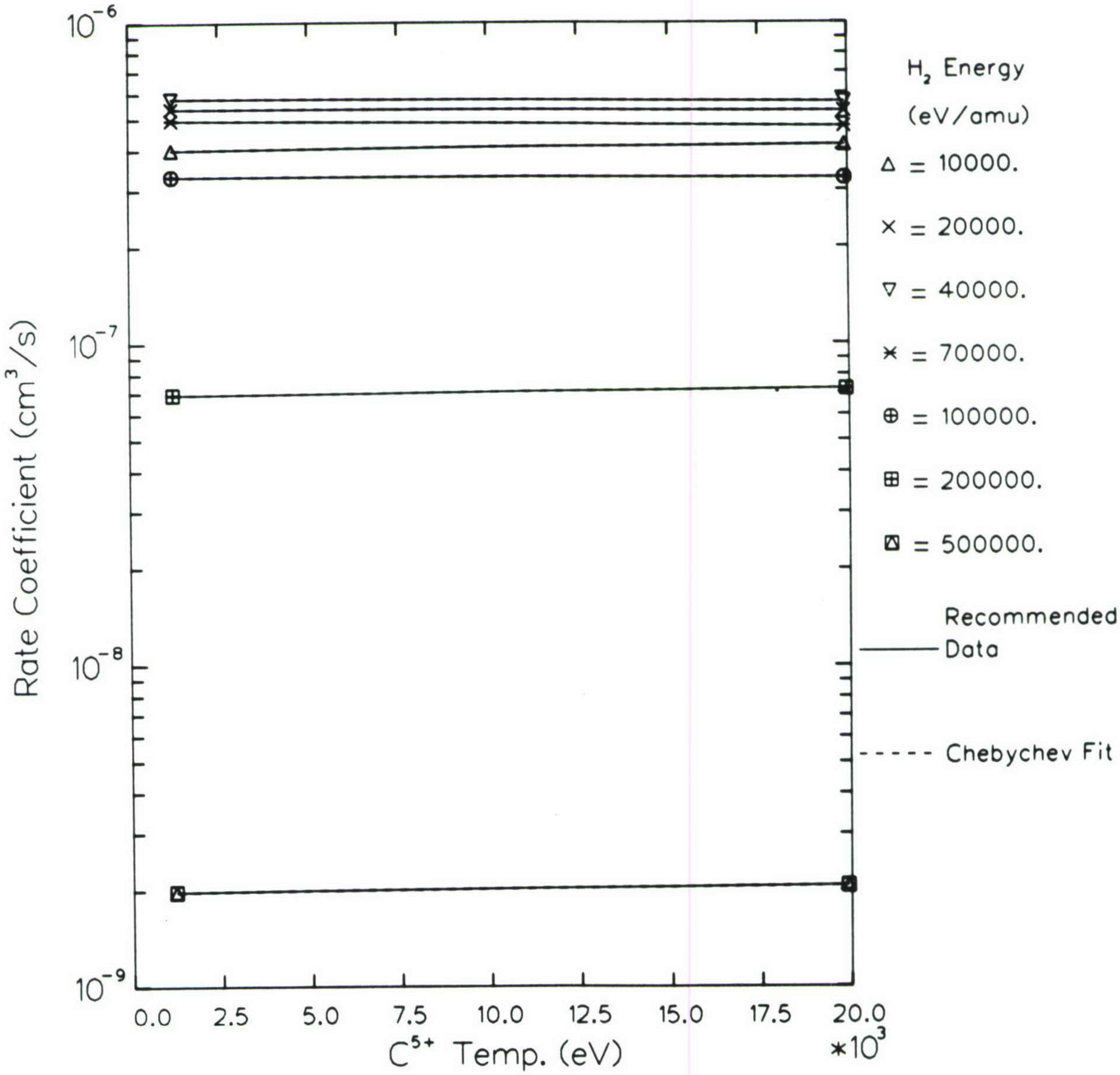
Chebychev Fitting Parameters for Rate Coefficients

H_2 Energy (eV/amu)	C1	C2	C3	C4	C5	C6	C7
10000.	8.098E-07	6.451E-09	2.130E-09	6.769E-10	6.752E-12	-1.292E-10	
20000.	1.067E-06	-5.097E-09	-1.361E-09	-5.588E-10	2.860E-10	5.306E-10	
40000.	1.147E-06	-7.633E-09	-2.065E-09	-1.597E-10	-5.517E-10	9.053E-10	
70000.	9.719E-07	-1.084E-08	-2.645E-09	-3.476E-10	1.014E-11	-4.715E-10	
100000.	6.581E-07	-1.805E-09	-6.328E-10	-2.115E-10	6.463E-11	7.555E-11	
200000.	1.400E-07	1.252E-09	4.327E-10	9.099E-11	-8.495E-13	1.609E-11	
500000.	4.016E-09	4.227E-11	1.400E-11	3.565E-12	8.101E-13	-6.606E-13	

See appendix for Chebychev fit details.

$H_2 + C^{5+} \rightarrow C^{4+} + H_2^+$

Beam – Maxwellian



Total Electron Capture Cross Sections for
$C^{6+} + H_2 \rightarrow C^{5+} + H_2^+$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
1.0E+02	1.39E+07	2.93E-15
2.0E+02	1.96E+07	3.80E-15
4.0E+02	2.78E+07	4.24E-15
7.0E+02	3.68E+07	4.50E-15
1.0E+03	4.39E+07	4.45E-15
1.7E+03	5.66E+07	4.40E-15
2.0E+03	6.21E+07	4.37E-15
4.0E+03	8.79E+07	4.12E-15
7.0E+03	1.16E+08	3.93E-15
1.0E+04	1.39E+08	3.74E-15
2.0E+04	1.96E+08	3.21E-15
4.0E+04	2.78E+08	2.31E-15
7.0E+04	3.68E+08	1.43E-15
1.0E+05	4.39E+08	9.30E-16
2.0E+05	6.21E+08	2.34E-16
4.0E+05	8.78E+08	2.33E-17
7.0E+05	1.16E+09	1.66E-18
1.0E+06	1.39E+09	2.48E-19
1.3E+06	1.55E+09	7.88E-20

References: E.3, E.8, E.9, E.11, E.34, E.35, E.46, E.54, T.49, T.50

Accuracy: 15% for $1.5\times10^2 \le E(eV/amu) \le 1\times10^4$; 30% for $1\times10^4 \le E(eV/amu) < 1\times10^5$; 15% for $1\times10^5 \le E(eV/amu) \le 2.2\times10^5$; 25% for $E > 2.2\times10^5$ eV/amu

Notes: (1) For energies below ~ 10^2 eV/amu, the cross section is expected to decrease with decreasing energy.

(2) There is experimental evidence [E.35] that the n=4 shell is dominantly populated in the region $1\times10^3 \lesssim E(eV/amu) \lesssim 1\times10^4$, but for higher energies capture to $n \lesssim 3$ shells should become increasingly important.

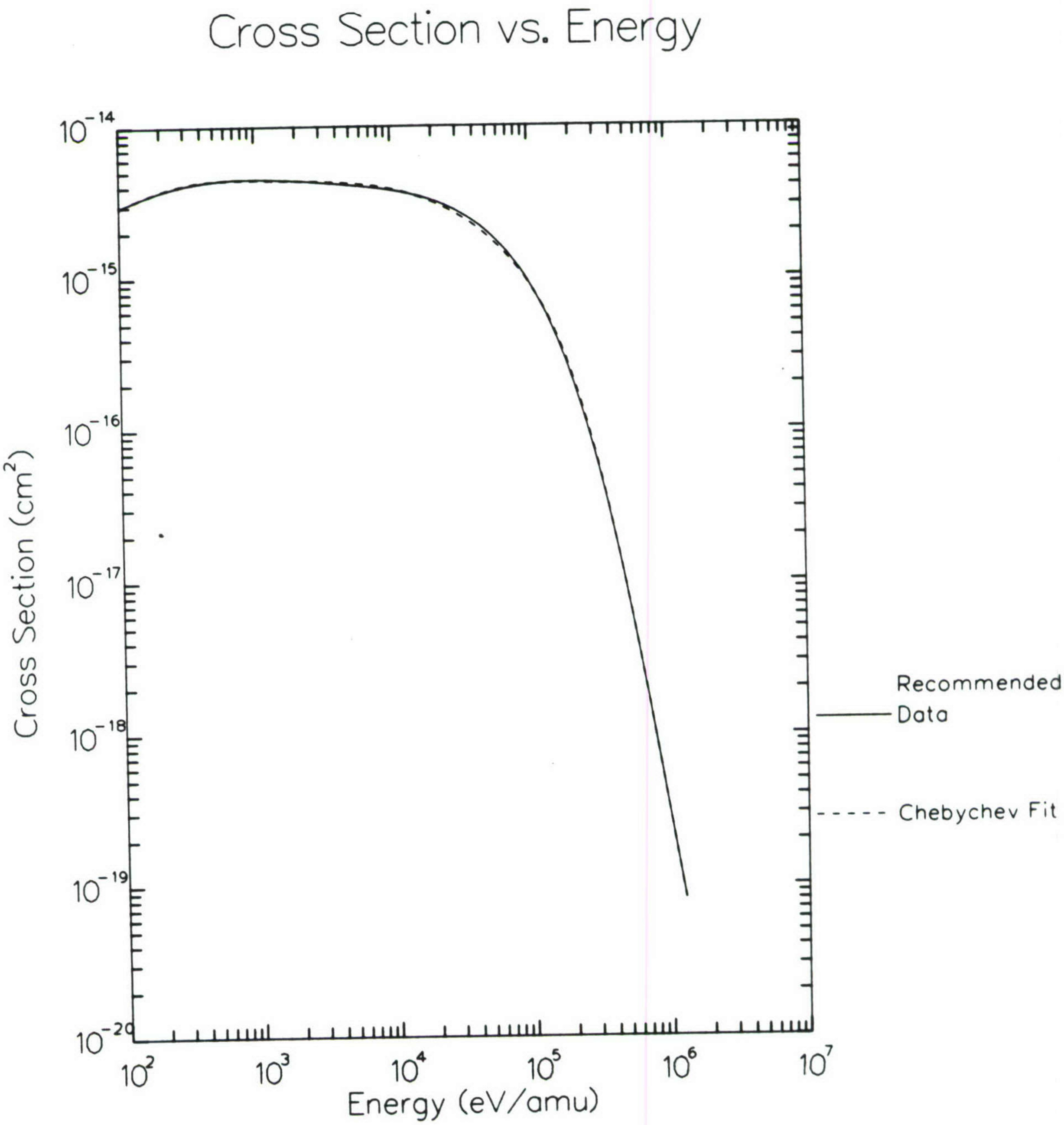
For Chebychev fits of the above cross sections it is necessary to use the following parameters.
E_{min} = 1.0E+02 eV/amu, E_{max} = 1.3E+06 eV/amu

Chebychev Fitting Parameters for Cross Sections

C1	C2	C3	C4	C5	C6	C7	C8	C9
4.679E-15	-2.180E-15	-9.865E-16	7.428E-16	2.041E-16	2.812E-17	-1.508E-16	-5.471E-17	5.739E-17

The fit represents the above cross sections with an rms deviation of 3.6%.
The maximum deviation is 11.5% at 2.0E+05 eV/amu.
See appendix for Chebychev fit details.

$C^{6+} + H_2 \rightarrow C^{5+} + H_2^{+}$



Total Electron Capture Rate Coefficients for
$C^{6+} + H_2 \rightarrow C^{5+} + H_2^+$

Maxwellian - Maxwellian Rate Coefficients (cm^3/s)

C^{6+} Temp. (eV)	Equal Temp.	H_2 Temp. (eV) 1.	10.	100.	1000.	5000.	10000.	20000.
1.2E+03	1.78E-07	4.41E-08*	4.62E-08*	6.54E-08*	1.65E-07	3.26E-07	4.21E-07	5.13E-07
2.4E+03	2.49E-07	8.29E-08	8.43E-08	9.73E-08	1.78E-07	3.31E-07	4.24E-07	5.14E-07
4.8E+03	3.36E-07	1.31E-07	1.32E-07	1.40E-07	2.02E-07	3.41E-07	4.30E-07	5.16E-07
8.4E+03	4.15E-07	1.78E-07	1.79E-07	1.85E-07	2.32E-07	3.54E-07	4.37E-07	5.19E-07
1.2E+04	4.66E-07	2.13E-07	2.13E-07	2.18E-07	2.57E-07	3.67E-07	4.45E-07	5.22E-07
2.0E+04	5.27E-07	2.69E-07	2.69E-07	2.72E-07	3.01E-07	3.92E-07	4.60E-07	5.28E-07

Accuracy: * - Possible Error Greater Than 10%
** - Possible Error Greater Than 100%

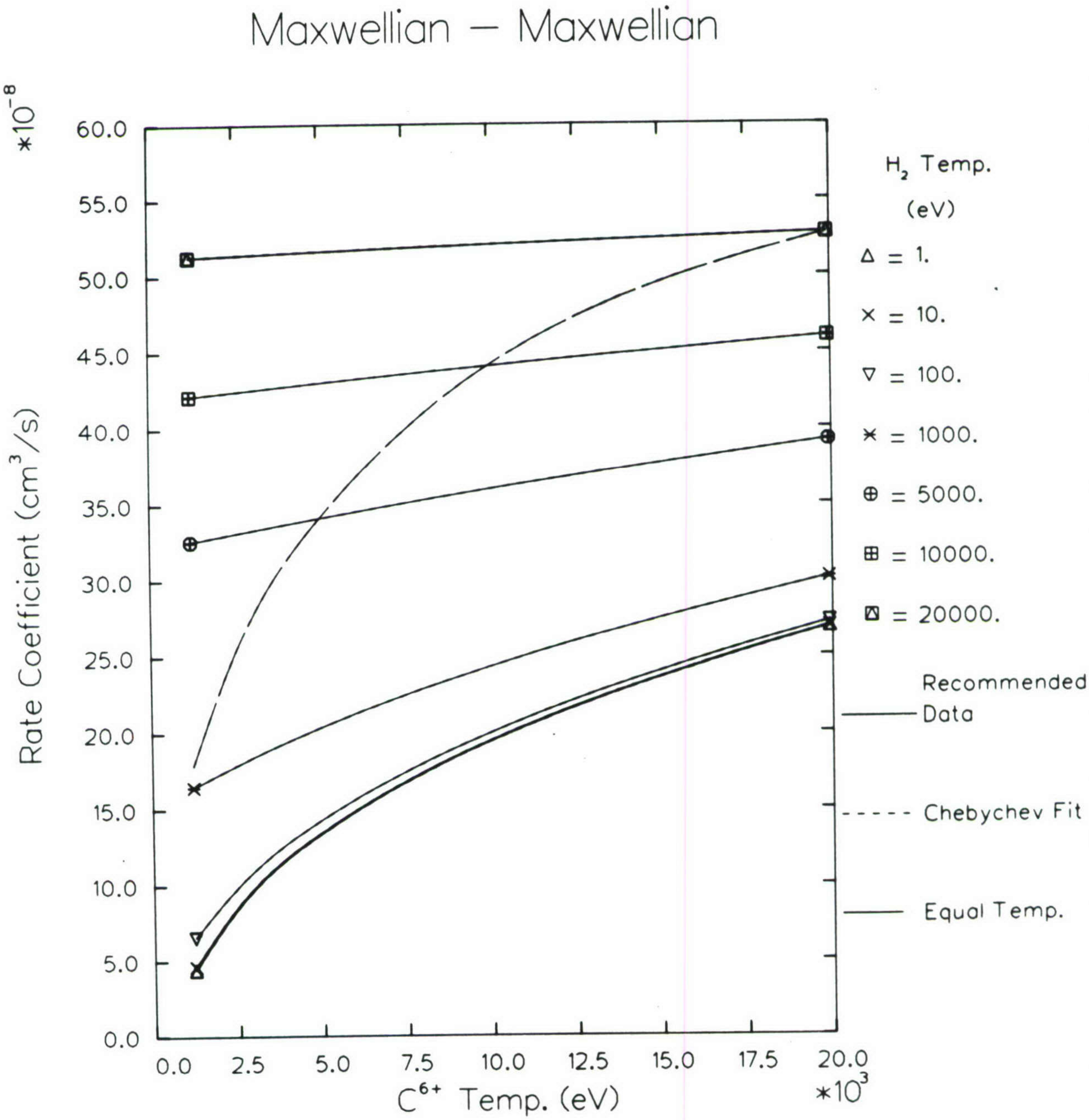
Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.2E+03 eV, E_{max} = 2.0E+04 eV

Chebychev Fitting Parameters for Rate Coefficients

H_2 Temp. (eV)	C1	C2	C3	C4	C5	C6	C7
1.	2.889E-07	1.116E-07	1.187E-08	7.942E-10	8.259E-11	-4.933E-12	
10.	2.910E-07	1.107E-07	1.207E-08	7.744E-10	7.494E-11	1.249E-12	
100.	3.105E-07	1.027E-07	1.354E-08	6.866E-10	6.027E-11	-8.144E-12	
1000.	4.360E-07	6.696E-08	1.494E-08	1.456E-09	-4.090E-11	-2.337E-11	
5000.	6.993E-07	3.158E-08	8.904E-09	1.462E-09	1.047E-10	-2.236E-11	
10000.	8.701E-07	1.818E-08	5.309E-09	9.416E-10	8.757E-11	-8.763E-12	
20000.	1.036E-06	7.153E-09	2.100E-09	3.756E-10	3.546E-11	-3.822E-12	
Equal Temp.	6.944E-07	1.795E-07	7.289E-09	-4.782E-09	-1.707E-09	-2.199E-10	

See appendix for Chebychev fit details.

$C^{6+} + H_2 \rightarrow C^{5+} + H_2^+$



Total Electron Capture Rate Coefficients for
$H_2 + C^{6+} \rightarrow C^{5+} + H_2^+$

Beam - Maxwellian Rate Coefficients (cm^3/s)

C^{6+} Temp. (eV)	H_2 Energy (eV/amu) 10000.	20000.	40000.	70000.	100000.	200000.	500000.
1.2E+03	5.19E-07	6.28E-07	6.39E-07	5.25E-07	4.07E-07	1.45E-07	8.69E-09
2.4E+03	5.20E-07	6.26E-07	6.38E-07	5.24E-07	4.06E-07	1.45E-07	8.72E-09
4.8E+03	5.22E-07	6.25E-07	6.34E-07	5.23E-07	4.05E-07	1.45E-07	8.76E-09
8.4E+03	5.24E-07	6.23E-07	6.32E-07	5.20E-07	4.04E-07	1.45E-07	8.82E-09
1.2E+04	5.26E-07	6.19E-07	6.28E-07	5.19E-07	4.02E-07	1.46E-07	8.89E-09
2.0E+04	5.30E-07	6.15E-07	6.21E-07	5.15E-07	4.00E-07	1.46E-07	9.04E-09

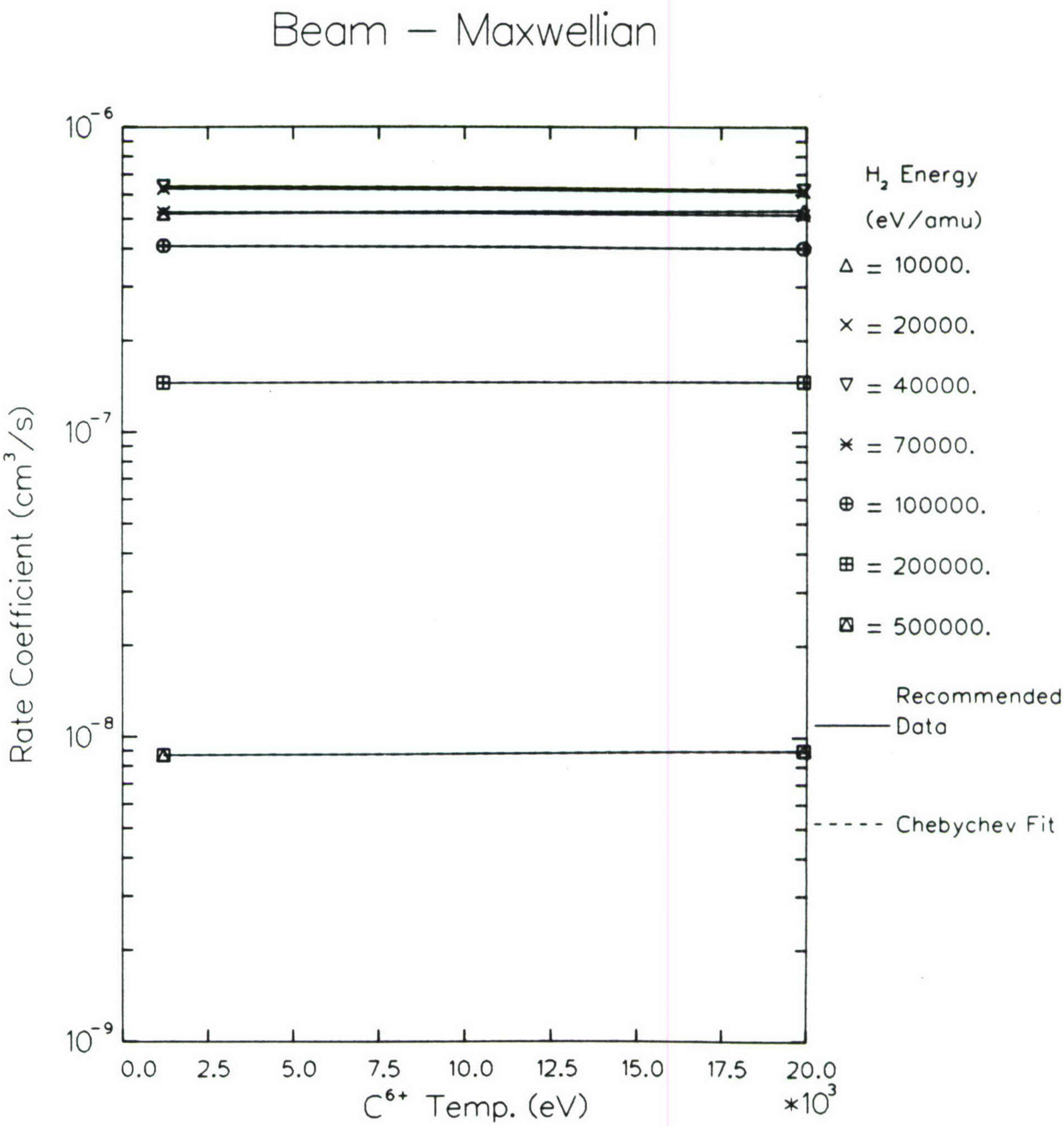
Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.2E+03 eV, E_{max} = 2.0E+04 eV

Chebychev Fitting Parameters for Rate Coefficients

H_2 Energy (eV/amu)	C1	C2	C3	C4	C5	C6	C7
10000.	1.046E-06	5.243E-09	1.471E-09	4.497E-10	-6.956E-11	-1.492E-10	
20000.	1.246E-06	-6.463E-09	-1.524E-09	-6.303E-10	3.108E-10	5.720E-10	
40000.	1.266E-06	-9.473E-09	-1.914E-09	-4.168E-10	-4.438E-10	9.301E-10	
70000.	1.042E-06	-4.059E-09	-1.437E-09	-2.078E-10	2.197E-11	-6.101E-10	
100000.	8.087E-07	-3.608E-09	-9.099E-10	-1.999E-10	1.410E-10	1.445E-10	
200000.	2.909E-07	3.695E-10	2.223E-10	3.917E-11	-3.416E-11	3.596E-11	
500000.	1.762E-08	1.620E-10	5.258E-11	1.300E-11	2.845E-12	-3.063E-12	

See appendix for Chebychev fit details.

$H_2 + C^{6+} \rightarrow C^{5+} + H_2^+$



Total Electron Capture Cross Sections for
$O^+ + H_2 \rightarrow O + H_2^+$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
5.6E+00	3.29E+06	6.68E-16
7.0E+00	3.68E+06	7.13E-16
1.0E+01	4.39E+06	7.89E-16
1.5E+01	5.38E+06	8.44E-16
2.0E+01	6.21E+06	8.01E-16
4.0E+01	8.79E+06	5.55E-16
7.0E+01	1.16E+07	4.25E-16
1.0E+02	1.39E+07	3.82E-16
1.2E+02	1.52E+07	3.73E-16
2.0E+02	1.96E+07	4.38E-16
4.0E+02	2.78E+07	6.52E-16
7.0E+02	3.68E+07	9.61E-16
1.0E+03	4.39E+07	1.12E-15
1.3E+03	4.91E+07	1.19E-15
2.0E+03	6.21E+07	1.24E-15
4.0E+03	8.79E+07	9.59E-16
7.0E+03	1.16E+08	6.43E-16
1.0E+04	1.39E+08	4.93E-16
2.0E+04	1.96E+08	2.88E-16
4.0E+04	2.78E+08	1.59E-16

References: E.1, E.2, E.38, E.47, E.48, E.49, E.57, E.58, E.59

Accuracy: 20% for $E \leq 1\times10^3$ eV/amu; 15% for $E > 1\times10^3$ eV/amu (see notes below)

Notes: (1) Most ion sources produce beams containing some admixture of ground-state $O^+(^4S)$ and metastable $O^+(^2D)$ ions. Typical relative abundances in ion beams are 70% ^4S and 30% ^2D [E.58]; these are probably typical of O^+ ions in a plasma. The recommended curve is believed to represent such a typical mixture of ground-state and metastable O^+ ions.

(2) Measurements in the 40-200 eV/amu energy range [E.58] with controlled O^+ initial-state distributions give capture cross sections of ~ 3×10^{-17} cm^2 for $O^+(^4S)$ and ~ 1×10^{-16} cm^2 for $O^+(^2D)$.

(3) The low-energy maximum in the cross section near 15 eV/amu is attributed to electron capture by O^+ leading to disociation of H_2^+ (dissociative charge transer) [E.2].

(4) At low energies, capture into the $O(^3P)$ ground state by $O^+(^2D)$ is more probable than by $O^+(^4S)$; formation of excited $O(^1D)$ products by $O^+(^2D)$ reactions is also most probable.

(5) Room-temperature reaction rate-coefficient measurements [E.60] indicate a cross section ~ 10^{-14} cm^2 at $E = 1.5\times10^{-2}$ eV/amu.

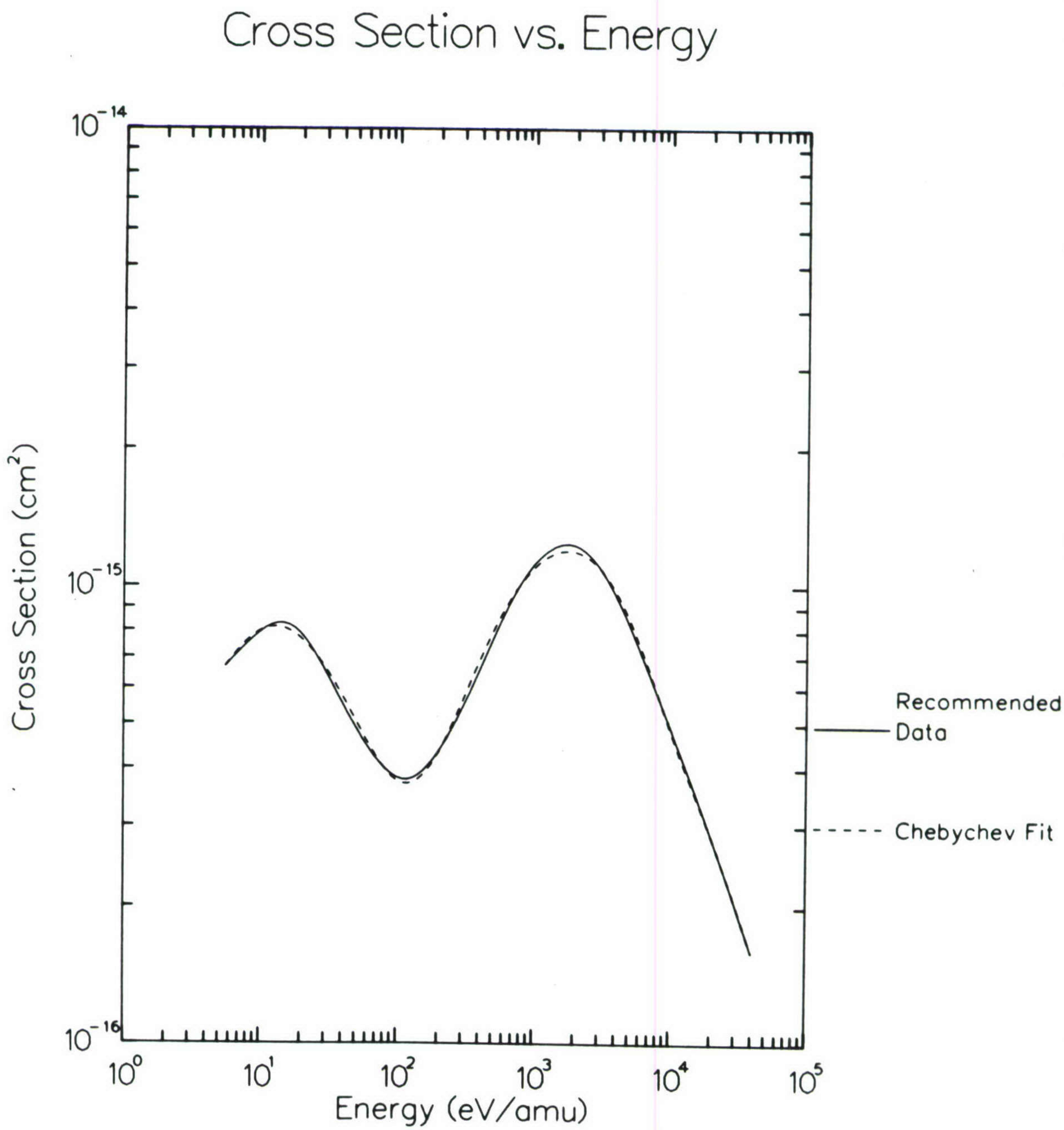
For Chebychev fits of the above cross sections it is necessary to use the following parameters.
E_{min} = 5.6E+00 eV/amu, E_{max} = 4.0E+04 eV/amu

Chebychev Fitting Parameters for Cross Sections

C1	C2	C3	C4	C5	C6	C7	C8	C9
1.238E-15	-1.625E-16	-1.817E-16	-2.260E-16	-6.139E-18	2.178E-16	-1.164E-18	-7.895E-17	-2.156E-17

The fit represents the above cross sections with an rms deviation of 2.9%.
The maximum deviation is 6.4% at 4.0E+02 eV/amu.
See appendix for Chebychev fit details.

$O^+ + H_2 \rightarrow O + H_2^+$



Total Electron Capture Rate Coefficients for
$O^+ + H_2 \rightarrow O + H_2^+$

Maxwellian - Maxwellian Rate Coefficients (cm^3/s)

O^+ Temp. (eV)	Equal Temp.	H_2 Temp. (eV) 1.	10.	100.	1000.	5000.	10000.	20000.
9.0E+01	5.31E-09	2.28E-09*	3.33E-09*	5.51E-09	3.36E-08	6.90E-08	7.01E-08	6.40E-08
1.1E+02	5.83E-09	2.70E-09*	3.53E-09	5.57E-09	3.36E-08	6.91E-08	7.01E-08	6.40E-08
1.6E+02	7.17E-09	3.31E-09*	3.85E-09	5.70E-09	3.38E-08	6.91E-08	7.01E-08	6.40E-08
2.4E+02	9.89E-09	3.89E-09	4.19E-09	5.92E-09	3.41E-08	6.91E-08	7.01E-08	6.40E-08
3.2E+02	1.29E-08	4.21E-09	4.41E-09	6.15E-09	3.43E-08	6.91E-08	7.01E-08	6.40E-08
6.4E+02	2.51E-08	4.95E-09	5.11E-09	7.17E-09	3.53E-08	6.92E-08	7.01E-08	6.40E-08
1.1E+03	3.96E-08	6.17E-09	6.39E-09	8.93E-09	3.68E-08	6.93E-08	7.01E-08	6.39E-08
1.6E+03	4.95E-08	7.76E-09	8.02E-09	1.09E-08	3.82E-08	6.94E-08	7.00E-08	6.39E-08
1.9E+03	5.42E-08	8.96E-09	9.25E-09	1.22E-08	3.91E-08	6.94E-08	7.00E-08	6.39E-08
3.2E+03	6.50E-08	1.43E-08	1.47E-08	1.78E-08	4.25E-08	6.96E-08	6.99E-08	6.38E-08
6.4E+03	7.08E-08	2.76E-08	2.79E-08	3.05E-08	4.95E-08	7.01E-08	6.97E-08	6.35E-08
1.1E+04	6.87E-08	4.25E-08	4.27E-08	4.45E-08	5.69E-08	7.05E-08	6.94E-08	6.32E-08
1.6E+04	6.53E-08	5.23E-08	5.24E-08	5.35E-08	6.17E-08	7.07E-08	6.91E-08	6.28E-08
2.0E+04	6.25E-08	5.78E-08	5.79E-08	5.87E-08	6.45E-08	7.08E-08	6.88E-08	6.25E-08

Accuracy: * - Possible Error Greater Than 10%
** - Possible Error Greater Than 100%

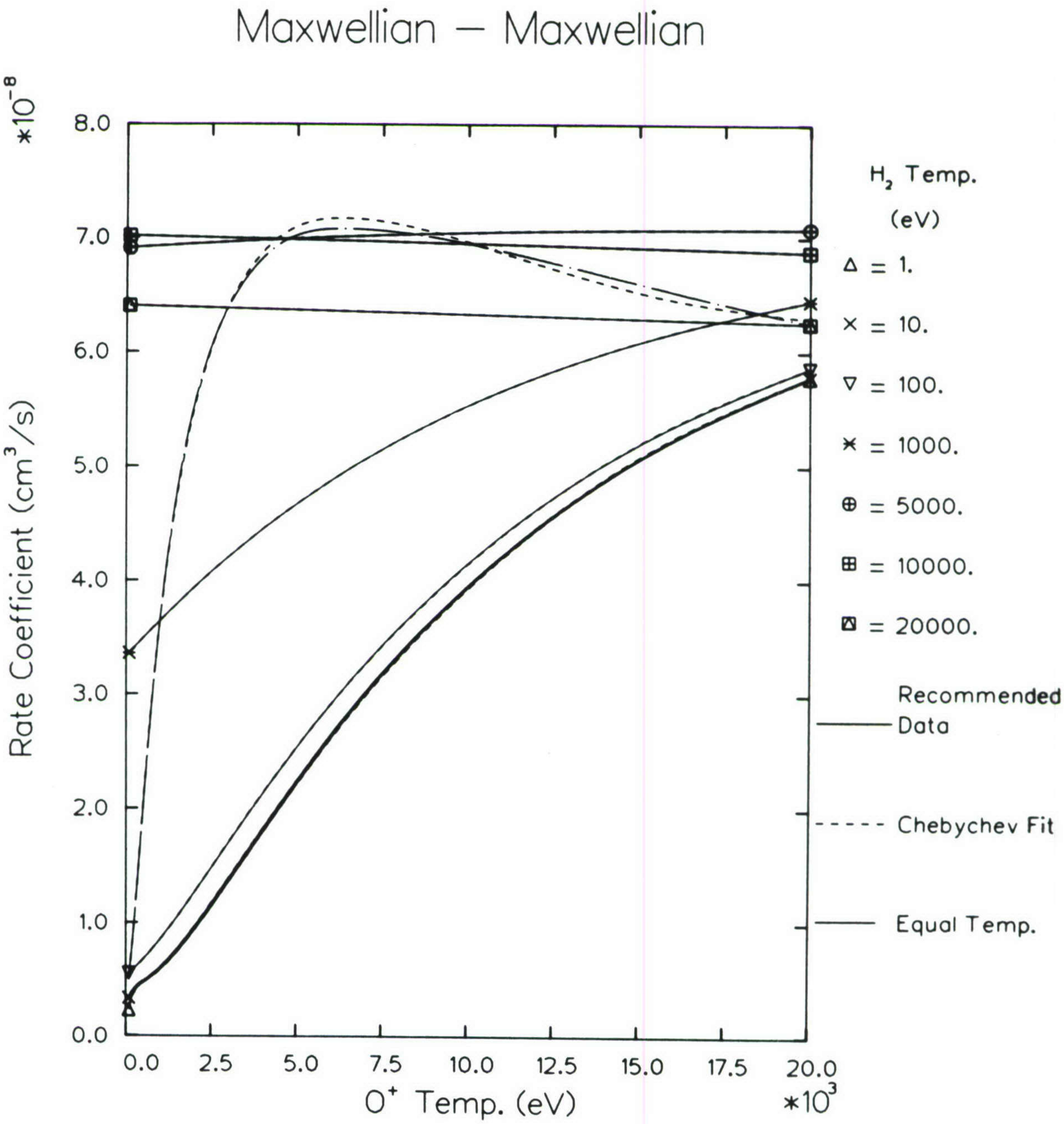
Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 9.0E+01 eV, E_{max} = 2.0E+04 eV

Chebychev Fitting Parameters for Rate Coefficients

H_2 Temp. (eV)	C1	C2	C3	C4	C5	C6	C7
1.	3.851E-08	2.552E-08	1.181E-08	3.092E-09	-8.192E-10	-8.457E-10	-2.092E-10
10.	3.923E-08	2.521E-08	1.198E-08	2.889E-09	-7.788E-10	-8.366E-10	-2.244E-10
100.	4.327E-08	2.499E-08	1.135E-08	2.276E-09	-7.002E-10	-6.892E-10	-1.998E-10
1000.	8.718E-08	1.481E-08	5.873E-09	9.346E-10	-3.399E-10	-2.752E-10	-8.143E-11
5000.	1.393E-07	8.839E-10	3.180E-10	1.675E-11	-4.847E-11	-3.181E-11	-1.138E-11
10000.	1.396E-07	-5.413E-10	-3.024E-10	-1.292E-10	-4.509E-11	-1.334E-11	-3.319E-12
20000.	1.273E-07	-6.044E-10	-3.201E-10	-1.245E-10	-3.750E-11	-8.945E-12	-1.638E-12
Equal Temp.	7.859E-08	3.636E-08	-5.504E-09	-9.369E-09	-8.125E-11	1.840E-09	4.131E-10

See appendix for Chebychev fit details.

$O^+ + H_2 \rightarrow O + H_2^+$



Total Electron Capture Rate Coefficients for
$H_2 + O^+ \rightarrow O + H_2^+$

Beam - Maxwellian Rate Coefficients (cm^3/s)

O^+ Temp. (eV)	H_2 Energy (eV/amu) 10000.	20000.	40000.	50000.	70000.	80000.	100000.
9.0E+01	6.85E-08	5.66E-08	4.42E-08	3.99E-08	3.36E-08	3.12E-08	2.72E-08
1.1E+02	6.85E-08	5.66E-08	4.42E-08	3.99E-08	3.36E-08	3.12E-08	2.72E-08
1.6E+02	6.85E-08	5.66E-08	4.42E-08	3.99E-08	3.36E-08	3.11E-08	2.72E-08
2.4E+02	6.85E-08	5.66E-08	4.42E-08	3.99E-08	3.36E-08	3.11E-08	2.72E-08
3.2E+02	6.84E-08	5.65E-08	4.42E-08	3.99E-08	3.36E-08	3.12E-08	2.72E-08
6.4E+02	6.85E-08	5.65E-08	4.41E-08	3.99E-08	3.36E-08	3.12E-08	2.72E-08
1.1E+03	6.84E-08	5.65E-08	4.41E-08	3.99E-08	3.36E-08	3.11E-08	2.72E-08
1.6E+03	6.83E-08	5.65E-08	4.41E-08	3.99E-08	3.36E-08	3.11E-08	2.72E-08
1.9E+03	6.84E-08	5.65E-08	4.41E-08	3.99E-08	3.36E-08	3.11E-08	2.72E-08
3.2E+03	6.83E-08	5.63E-08	4.41E-08	3.99E-08	3.36E-08	3.11E-08	2.71E-08
6.4E+03	6.82E-08	5.63E-08	4.39E-08	3.98E-08	3.36E-08	3.11E-08	2.71E-08
1.1E+04	6.79E-08	5.62E-08	4.39E-08	3.98E-08	3.35E-08	3.11E-08	2.70E-08
1.6E+04	6.75E-08	5.59E-08	4.38E-08	3.97E-08	3.35E-08	3.10E-08	2.69E-08
2.0E+04	6.71E-08	5.59E-08	4.38E-08	3.97E-08	3.35E-08	3.10E-08	2.69E-08

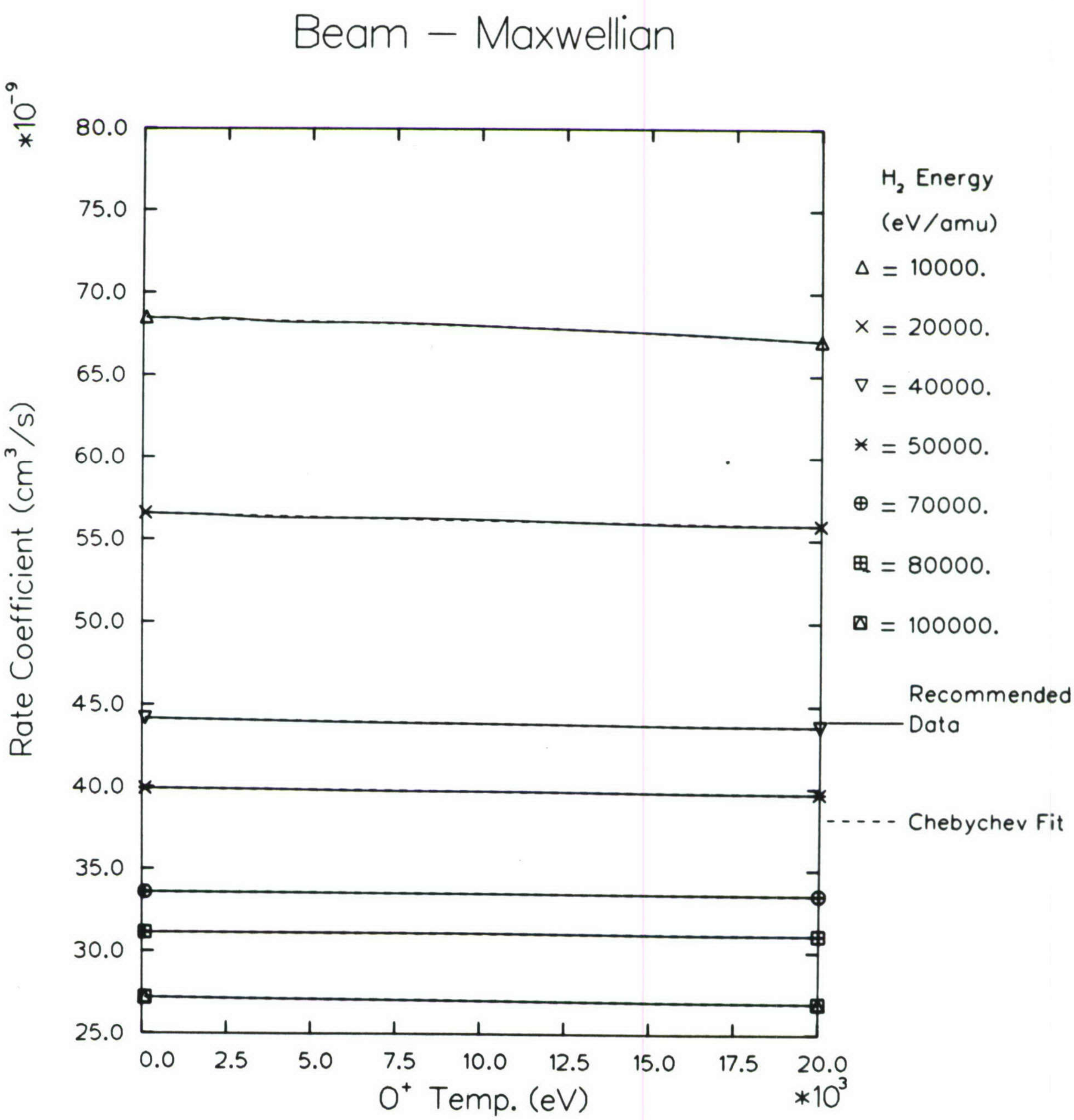
Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 9.0E+01 eV, E_{max} = 2.0E+04 eV

Chebychev Fitting Parameters for Rate Coefficients

H_2 Energy (eV/amu)	C1	C2	C3	C4	C5	C6	C7
10000.	1.363E-07	-4.915E-10	-2.801E-10	-1.581E-10	-8.221E-11	-3.975E-11	-1.743E-11
20000.	1.127E-07	-3.080E-10	-1.343E-10	-4.489E-11	-1.199E-11	-1.377E-12	-1.984E-12
40000.	8.807E-08	-1.922E-10	-8.192E-11	-2.099E-11	8.315E-13	4.468E-12	5.618E-13
50000.	7.969E-08	-1.109E-10	-5.258E-11	-1.777E-11	-3.127E-12	3.783E-12	9.397E-13
70000.	6.711E-08	-5.738E-11	-2.847E-11	-8.149E-12	8.678E-13	4.053E-12	3.764E-12
80000.	6.224E-08	-4.370E-11	-2.743E-11	-1.776E-11	8.306E-13	-1.780E-12	5.732E-13
100000.	5.424E-08	-1.395E-10	-5.446E-11	-1.438E-11	-2.569E-12	-2.348E-13	2.552E-12

See appendix for Chebychev fit details.

$H_2 + O^+ \to O + H_2^+$



Beam – Maxwellian
*10^-9
80.0
75.0
70.0
65.0
60.0
55.0
50.0
45.0
40.0
35.0
30.0
25.0
Rate Coefficient (cm^3/s)
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
20.0
*10^3
O^+ Temp. (eV)
H_2 Energy
(eV/amu)
Δ = 10000.
× = 20000.
∇ = 40000.
* = 50000.
⊕ = 70000.
⊞ = 80000.
⊠ = 100000.
Recommended Data
Chebychev Fit

Total Electron Capture Cross Sections for
$O^{2+} + H_2 \rightarrow O^+ + H_2^+$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
1.8E+02	1.86E+07	1.25E-16
2.0E+02	1.96E+07	1.32E-16
4.0E+02	2.78E+07	1.78E-16
7.0E+02	3.68E+07	2.23E-16
1.0E+03	4.39E+07	2.56E-16
1.3E+03	4.91E+07	2.80E-16
2.0E+03	6.21E+07	3.36E-16
4.0E+03	8.79E+07	4.21E-16
7.0E+03	1.16E+08	4.80E-16
1.0E+04	1.39E+08	5.08E-16
2.0E+04	1.96E+08	5.40E-16
4.0E+04	2.78E+08	4.55E-16

References: E.1, E.8, E.38, E.54, E.59

Accuracy: 20% for the entire energy region shown

Notes: (1) O^{2+} beams produced in ion sources or by foil or gas stripping at higher energies likely contain some admixture of ground-state (^3P) and metastable (^1S and ^1D) ions. The recommended cross-section curve is believed to represent such an admixture which is typical of both ion sources and plasmas.
(2) The reaction rate measurements at T ≈ 300 K [E.61] indicate that at E ≈ 1.45×10^{-2} eV/amu the cross section for reactant ground-state $O^2(^3P)$ is ≈ 1.1×10^{-14} cm^2, and with excited O^{2+} (probably ^1S and ^1D) is ≈ 2.1×10^{-14} cm^2.

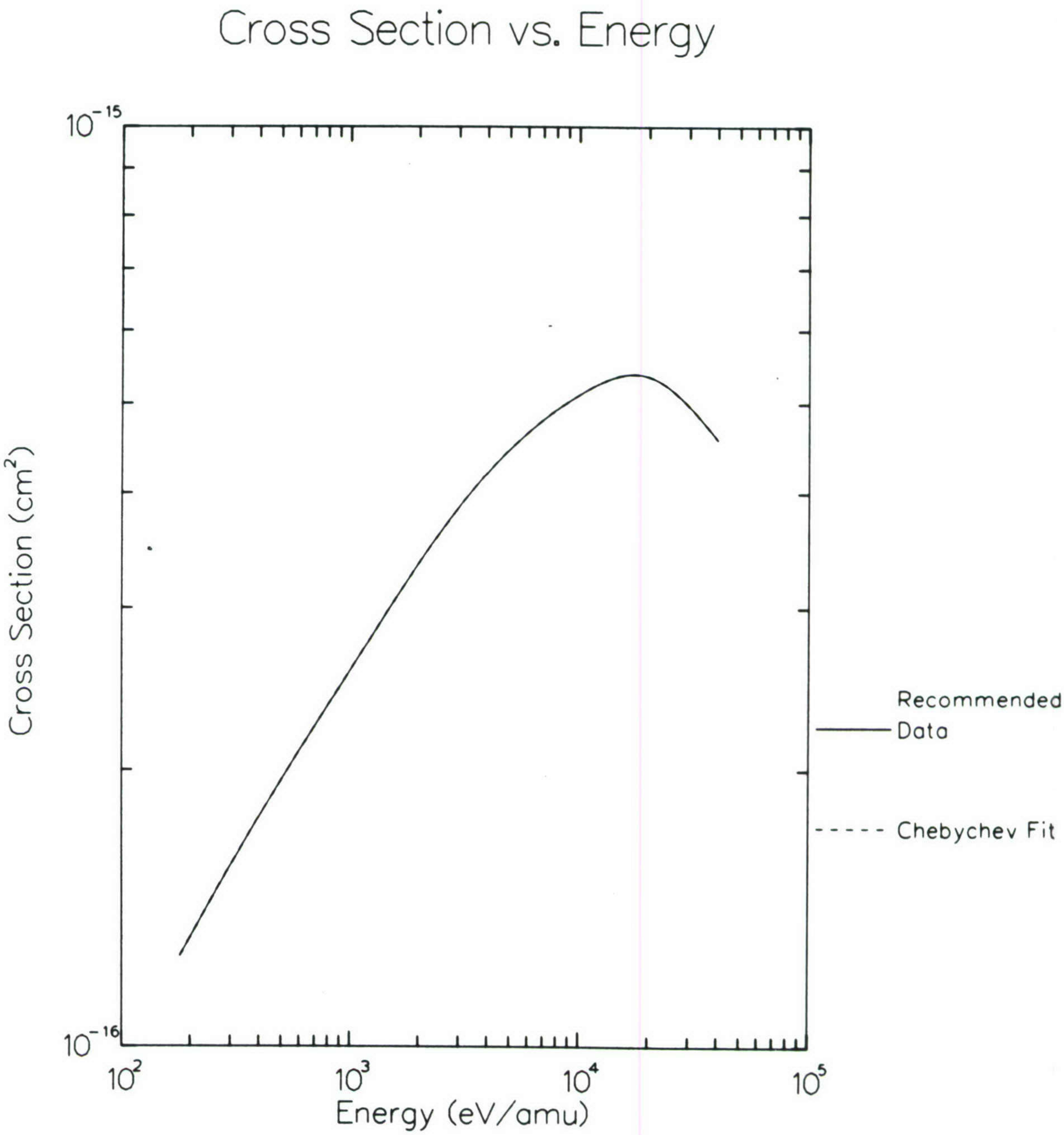
For Chebychev fits of the above cross sections it is necessary to use the following parameters.
E_{min} = 1.8E+02 eV/amu, E_{max} = 4.0E+04 eV/amu

Chebychev Fitting Parameters for Cross Sections

C1	C2	C3	C4	C5	C6	C7	C8	C9
6.911E-16	2.132E-16	-3.646E-17	-4.115E-17	-1.333E-17	-3.855E-18	-4.740E-18	-3.247E-18	-1.021E-18

The fit represents the above cross sections with an rms deviation of 0.1%.
The maximum deviation is 0.2% at 1.0E+03 eV/amu.
See appendix for Chebychev fit details.

$O^{2+} + H_2 \rightarrow O^{+} + H_2^{+}$



Total Electron Capture Rate Coefficients for
$O^{2+} + H_2 \rightarrow O^+ + H_2^+$

Maxwellian - Maxwellian Rate Coefficients (cm^3/s)

O^{2+} Temp. (eV)	Equal Temp.	H_2 Temp. (eV) 1.	10.	100.	1000.	5000.	10000.	20000.
2.9E+03	2.29E-08	2.81E-09*	2.90E-09*	3.75E-09*	1.09E-08	3.38E-08	5.33E-08	7.67E-08
3.2E+03	2.49E-08	3.20E-09*	3.28E-09*	4.12E-09*	1.12E-08	3.40E-08	5.34E-08	7.67E-08
6.4E+03	4.18E-08	6.67E-09	6.74E-09	7.46E-09	1.40E-08	3.58E-08	5.47E-08	7.74E-08
1.1E+04	6.00E-08	1.12E-08	1.13E-08	1.19E-08	1.79E-08	3.85E-08	5.65E-08	7.83E-08
1.6E+04	7.25E-08	1.53E-08	1.54E-08	1.60E-08	2.15E-08	4.10E-08	5.83E-08	7.91E-08
2.0E+04	7.98E-08	1.85E-08	1.86E-08	1.91E-08	2.44E-08	4.30E-08	5.97E-08	7.98E-08

Accuracy: * - Possible Error Greater Than 10%
** - Possible Error Greater Than 100%

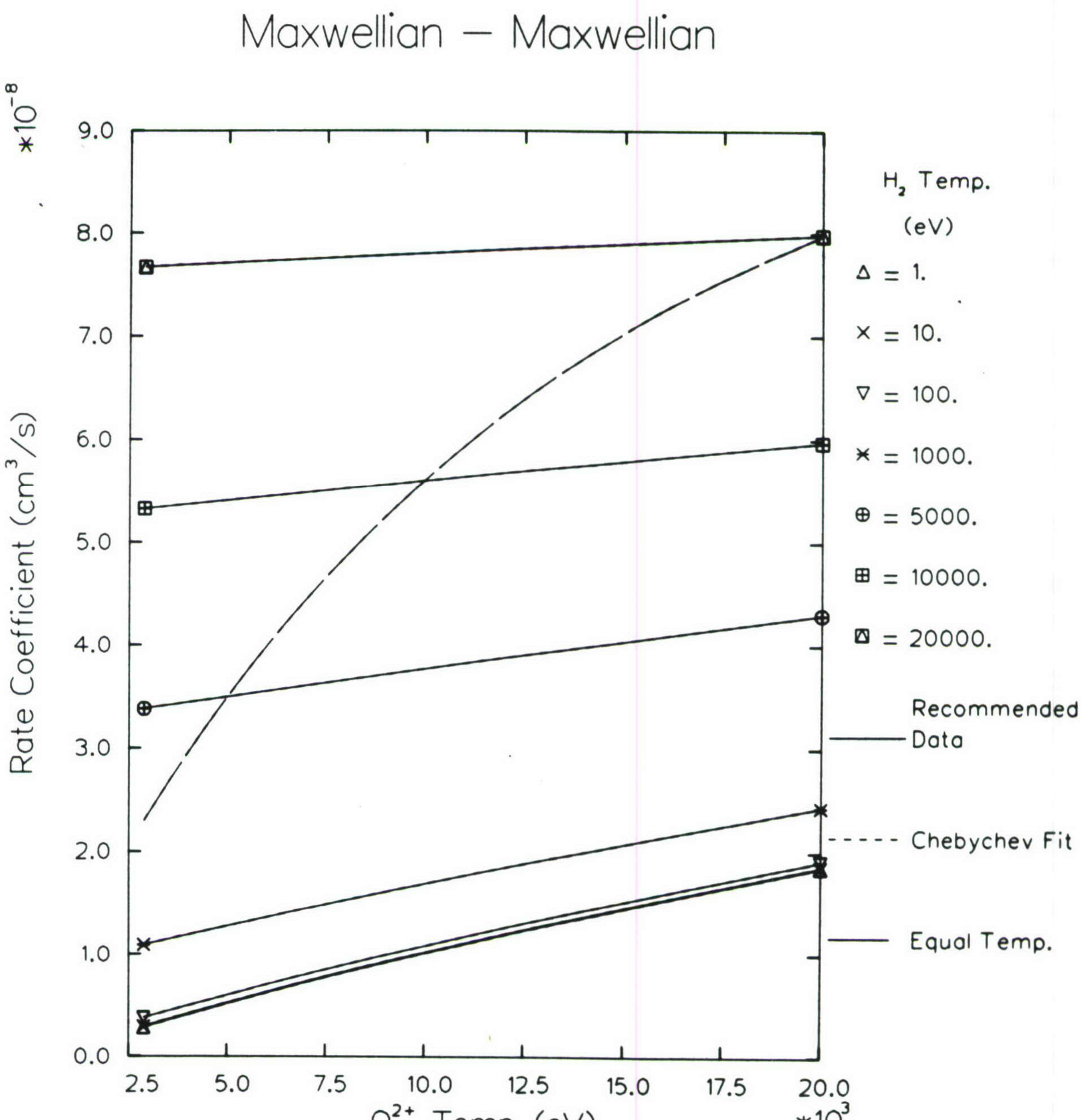
Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 2.9E+03 eV, E_{max} = 2.0E+04 eV

Chebychev Fitting Parameters for Rate Coefficients

H_2 Temp. (eV)	C1	C2	C3	C4	C5	C6	C7
1.	1.850E-08	7.687E-09	1.409E-09	1.711E-10	8.930E-12	-1.387E-12	
10.	1.864E-08	7.671E-09	1.409E-09	1.706E-10	8.882E-12	-1.339E-12	
100.	2.004E-08	7.525E-09	1.414E-09	1.670E-10	8.644E-12	-1.018E-12	
1000.	3.262E-08	6.561E-09	1.324E-09	1.561E-10	8.414E-12	-6.512E-13	
5000.	7.484E-08	4.466E-09	9.542E-10	1.185E-10	7.886E-12	1.857E-12	
10000.	1.116E-07	3.143E-09	6.909E-10	1.000E-10	8.916E-13	-6.757E-12	
20000.	1.558E-07	1.514E-09	3.224E-10	4.162E-11	2.751E-12	-1.281E-13	
Equal Temp.	9.867E-08	2.900E-08	2.195E-09	-5.406E-10	-1.895E-10	-2.275E-11	

See appendix for Chebychev fit details.

$O^{2+} + H_2 \rightarrow O^{+} + H_2^{+}$



Total Electron Capture Rate Coefficients for
$H_2 + O^{2+} \rightarrow O^+ + H_2^+$

Beam - Maxwellian Rate Coefficients (cm^3/s)

O^{2+} Temp. (eV)	H_2 Energy (eV/amu) 10000.	20000.	40000.	50000.	70000.	80000.	100000.
2.9E+03	7.13E-08	1.05E-07	1.24E-07	1.12E-07	8.03E-08	6.62E-08	2.37E-08*
3.2E+03	7.14E-08	1.05E-07	1.24E-07	1.12E-07	8.02E-08	6.62E-08	2.37E-08*
6.4E+03	7.19E-08	1.05E-07	1.22E-07	1.11E-07	8.02E-08	6.57E-08	2.45E-08*
1.1E+04	7.31E-08	1.05E-07	1.20E-07	1.10E-07	7.97E-08	6.44E-08	2.53E-08*
1.6E+04	7.44E-08	1.05E-07	1.19E-07	1.09E-07	7.90E-08	6.29E-08	2.60E-08*
2.0E+04	7.54E-08	1.05E-07	1.18E-07	1.08E-07	7.82E-08	6.18E-08	2.65E-08*

Accuracy: * - Possible Error Greater Than 10%
** - Possible Error Greater Than 100%

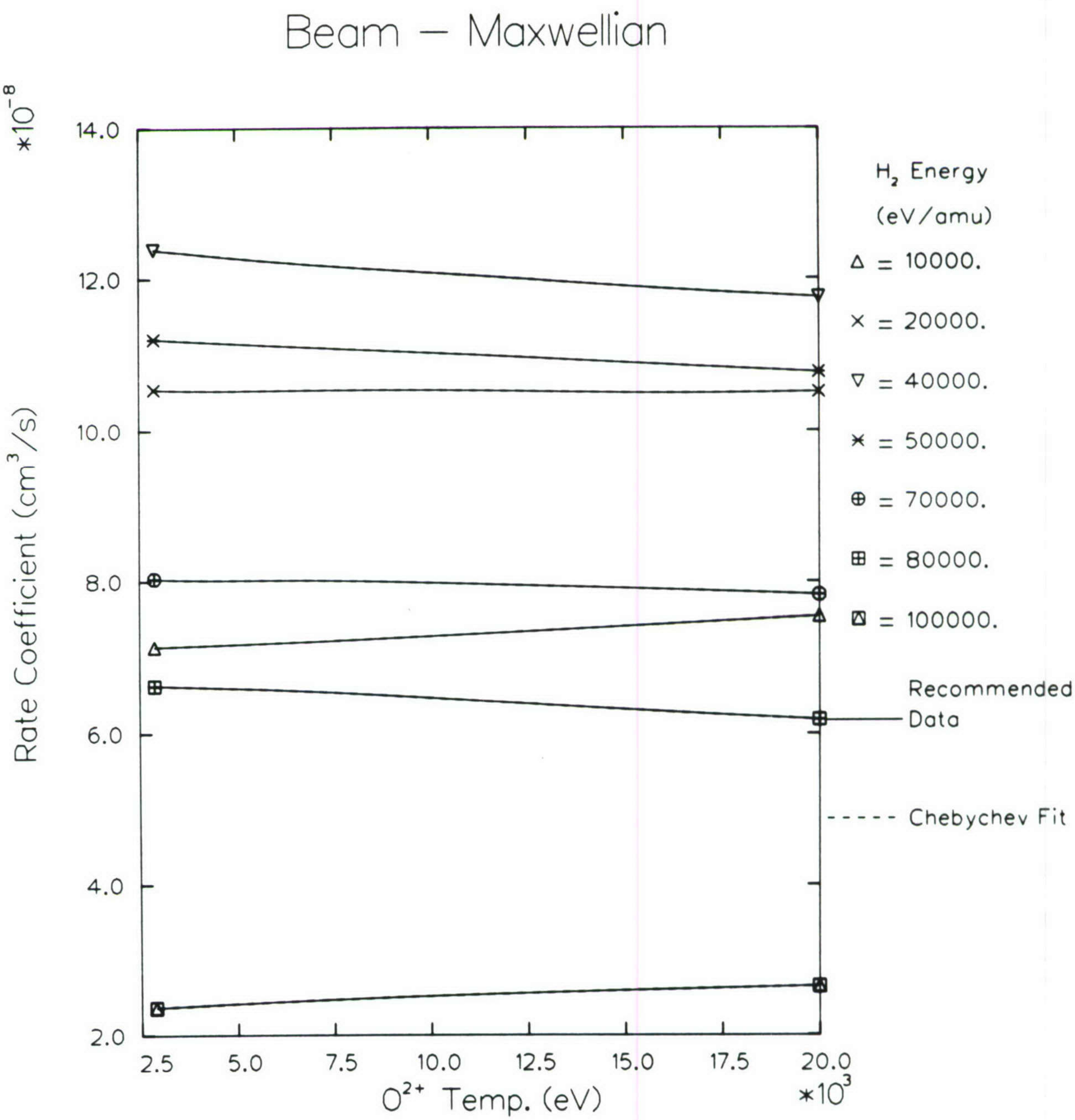
Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 2.9E+03 eV, E_{max} = 2.0E+04 eV

Chebychev Fitting Parameters for Rate Coefficients

H_2 Energy (eV/amu)	C1	C2	C3	C4	C5	C6	C7
10000.	1.456E-07	1.965E-09	5.796E-10	8.517E-11	-1.833E-11	5.455E-12	
20000.	2.103E-07	-1.763E-10	-5.772E-11	-4.445E-11	1.270E-10	4.984E-11	
40000.	2.422E-07	-3.117E-09	-4.653E-10	-1.107E-10	2.933E-11	6.316E-11	
50000.	2.206E-07	-2.102E-09	-4.670E-10	-1.037E-10	8.894E-12	3.593E-11	
70000.	1.593E-07	-8.924E-10	-4.202E-10	-1.295E-10	3.239E-11	-2.633E-11	
80000.	1.294E-07	-2.152E-09	-7.012E-10	-4.361E-11	2.855E-11	2.683E-12	
100000.	4.981E-08	1.409E-09	1.678E-10	1.114E-11	-1.399E-13	-1.610E-13	

See appendix for Chebychev fit details.

$H_2 + O^{2+} \rightarrow O^+ + H_2^+$



Total Electron Capture Cross Sections for
$O^{3+} + H_2 \rightarrow O^{2+} + H_2^+$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
4.0E+01	8.79E+06	2.75E-15
7.0E+01	1.16E+07	2.11E-15
1.0E+02	1.39E+07	1.80E-15
2.0E+02	1.96E+07	1.35E-15
4.0E+02	2.78E+07	1.09E-15
7.0E+02	3.68E+07	9.73E-16
1.0E+03	4.39E+07	9.28E-16
1.3E+03	4.91E+07	9.10E-16
1.4E+03	5.20E+07	9.20E-16
2.0E+03	6.21E+07	9.45E-16
4.0E+03	8.79E+07	1.10E-15
7.0E+03	1.16E+08	1.27E-15
1.0E+04	1.39E+08	1.37E-15
1.6E+04	1.76E+08	1.46E-15
2.0E+04	1.96E+08	1.44E-15
4.0E+04	2.78E+08	1.13E-15
7.0E+04	3.68E+08	5.03E-16
1.0E+05	4.39E+08	2.31E-16
1.4E+05	5.20E+08	1.02E-16

References: E.1, E.8, E.17, E.54, E.62

Accuracy: 30% for $50 \leq E(\text{eV/amu}) \leq 1\times10^3$; 15% for $E > 1\times10^3$ eV/amu

Note: In the energy region below $E \sim (1-2)\times10^3$ eV/amu capture dominantly goes to the 2p3l levels of the O^{2+} ion, and the cross section is expected to continue to increase with decreasing energy down to thermal energies.

For Chebychev fits of the above cross sections it is necessary to use the following parameters.
E_{min} = 4.0E+01 eV/amu, E_{max} = 1.4E+05 eV/amu

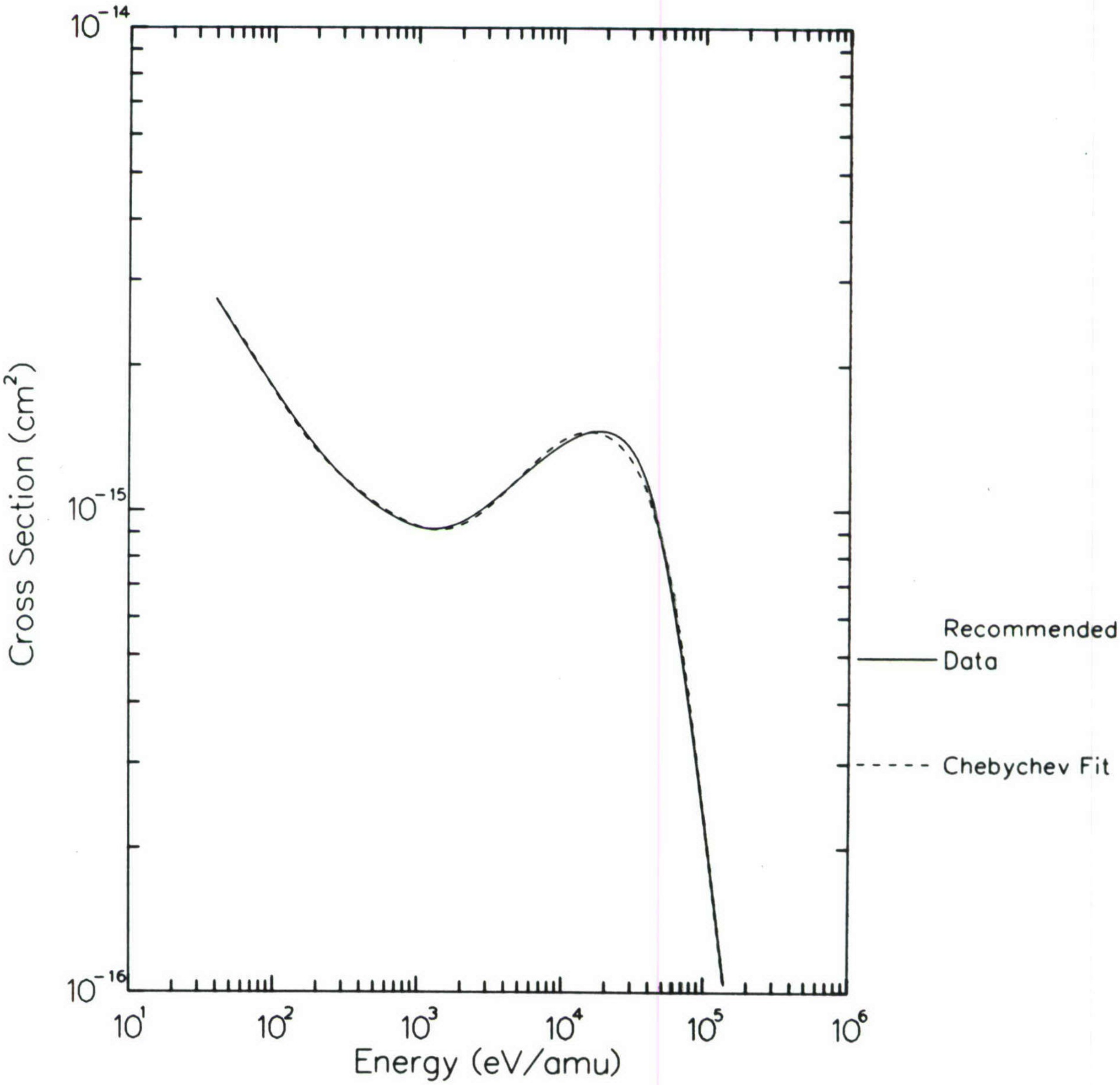
Chebychev Fitting Parameters for Cross Sections

C1	C2	C3	C4	C5	C6	C7	C8	C9
2.515E-15	-9.019E-16	1.427E-16	-5.300E-16	-5.065E-17	6.834E-17	8.905E-17	4.506E-17	-1.766E-17

The fit represents the above cross sections with an rms deviation of 2.2%.
The maximum deviation is 5.8% at 7.0E+04 eV/amu.
See appendix for Chebychev fit details.

$O^{3+} + H_2 \rightarrow O^{2+} + H_2^+$

Cross Section vs. Energy



Total Electron Capture Rate Coefficients for
$O^{3+} + H_2 \rightarrow O^{2+} + H_2^+$

Maxwellian - Maxwellian Rate Coefficients (cm^3/s)

O^{3+} Temp. (eV)	Equal Temp.	H_2 Temp. (eV) 1.	10.	100.	1000.	5000.	10000.	20000.
6.4E+02	3.21E-08	1.43E-08*	1.55E-08*	2.15E-08*	3.72E-08	8.97E-08	1.41E-07	2.02E-07
1.1E+03	3.97E-08	1.96E-08*	2.01E-08*	2.35E-08	3.80E-08	9.04E-08	1.42E-07	2.02E-07
1.6E+03	4.71E-08	2.23E-08*	2.26E-08*	2.51E-08	3.88E-08	9.11E-08	1.42E-07	2.02E-07
3.2E+03	7.12E-08	2.71E-08	2.72E-08	2.88E-08	4.16E-08	9.35E-08	1.44E-07	2.03E-07
6.4E+03	1.14E-07	3.33E-08	3.34E-08	3.47E-08	4.71E-08	9.81E-08	1.47E-07	2.05E-07
1.1E+04	1.61E-07	4.16E-08	4.17E-08	4.30E-08	5.53E-08	1.05E-07	1.52E-07	2.07E-07
1.6E+04	1.93E-07	4.98E-08	5.00E-08	5.12E-08	6.33E-08	1.11E-07	1.57E-07	2.09E-07
2.0E+04	2.10E-07	5.66E-08	5.68E-08	5.80E-08	6.99E-08	1.17E-07	1.60E-07	2.10E-07

Accuracy: * - Possible Error Greater Than 10%
** - Possible Error Greater Than 100%

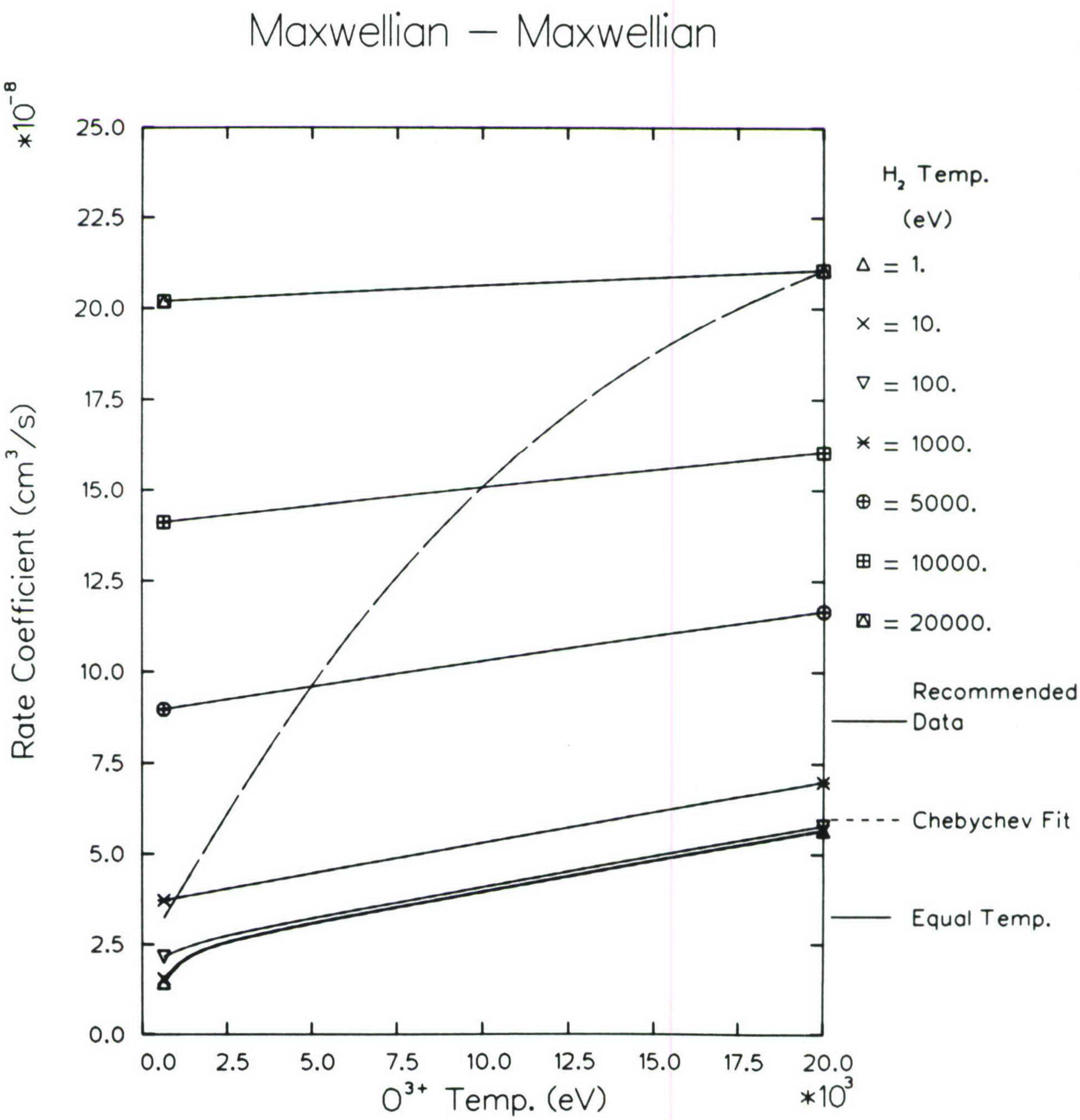
Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 6.4E+02 eV, E_{max} = 2.0E+04 eV

Chebychev Fitting Parameters for Rate Coefficients

H_2 Temp. (eV)	C1	C2	C3	C4	C5	C6	C7
1.	6.285E-08	1.905E-08	3.781E-09	2.056E-09	2.789E-10	3.746E-11	8.423E-12
10.	6.357E-08	1.866E-08	4.014E-09	1.961E-09	3.041E-10	3.444E-11	7.022E-12
100.	6.855E-08	1.660E-08	5.111E-09	1.592E-09	3.610E-10	3.840E-11	-1.266E-12
1000.	9.524E-08	1.484E-08	5.644E-09	1.479E-09	2.799E-10	3.453E-11	-9.690E-14
5000.	1.968E-07	1.235E-08	4.574E-09	1.138E-09	1.960E-10	2.016E-11	-8.185E-13
10000.	2.948E-07	8.812E-09	3.241E-09	7.941E-10	1.322E-10	1.221E-11	-1.258E-12
20000.	4.093E-07	3.951E-09	1.436E-09	3.423E-10	5.287E-11	3.371E-12	-1.116E-12
Equal Temp.	2.023E-07	9.025E-08	2.239E-08	-4.124E-10	-2.191E-09	-6.909E-10	-8.560E-11

See appendix for Chebychev fit details.

$O^{3+} + H_2 \rightarrow O^{2+} + H_2^+$



Total Electron Capture Rate Coefficients for
$H_2 + O^{3+} \rightarrow O^{2+} + H_2^+$

Beam - Maxwellian Rate Coefficients (cm^3/s)

O^{3+} Temp. (eV)	H_2 Energy (eV/amu) 10000.	20000.	40000.	50000.	70000.	80000.	100000.
6.4E+02	1.91E-07	2.82E-07	3.11E-07	2.71E-07	1.85E-07	1.51E-07	1.02E-07
1.1E+03	1.91E-07	2.83E-07	3.10E-07	2.71E-07	1.85E-07	1.51E-07	1.02E-07
1.6E+03	1.91E-07	2.82E-07	3.10E-07	2.71E-07	1.85E-07	1.51E-07	1.02E-07
3.2E+03	1.92E-07	2.81E-07	3.07E-07	2.70E-07	1.85E-07	1.51E-07	1.02E-07
6.4E+03	1.95E-07	2.81E-07	3.03E-07	2.68E-07	1.85E-07	1.51E-07	1.03E-07
1.1E+04	1.98E-07	2.80E-07	2.99E-07	2.65E-07	1.84E-07	1.52E-07	1.03E-07
1.6E+04	2.01E-07	2.78E-07	2.94E-07	2.62E-07	1.84E-07	1.52E-07	1.03E-07
2.0E+04	2.03E-07	2.78E-07	2.92E-07	2.60E-07	1.84E-07	1.51E-07	1.03E-07

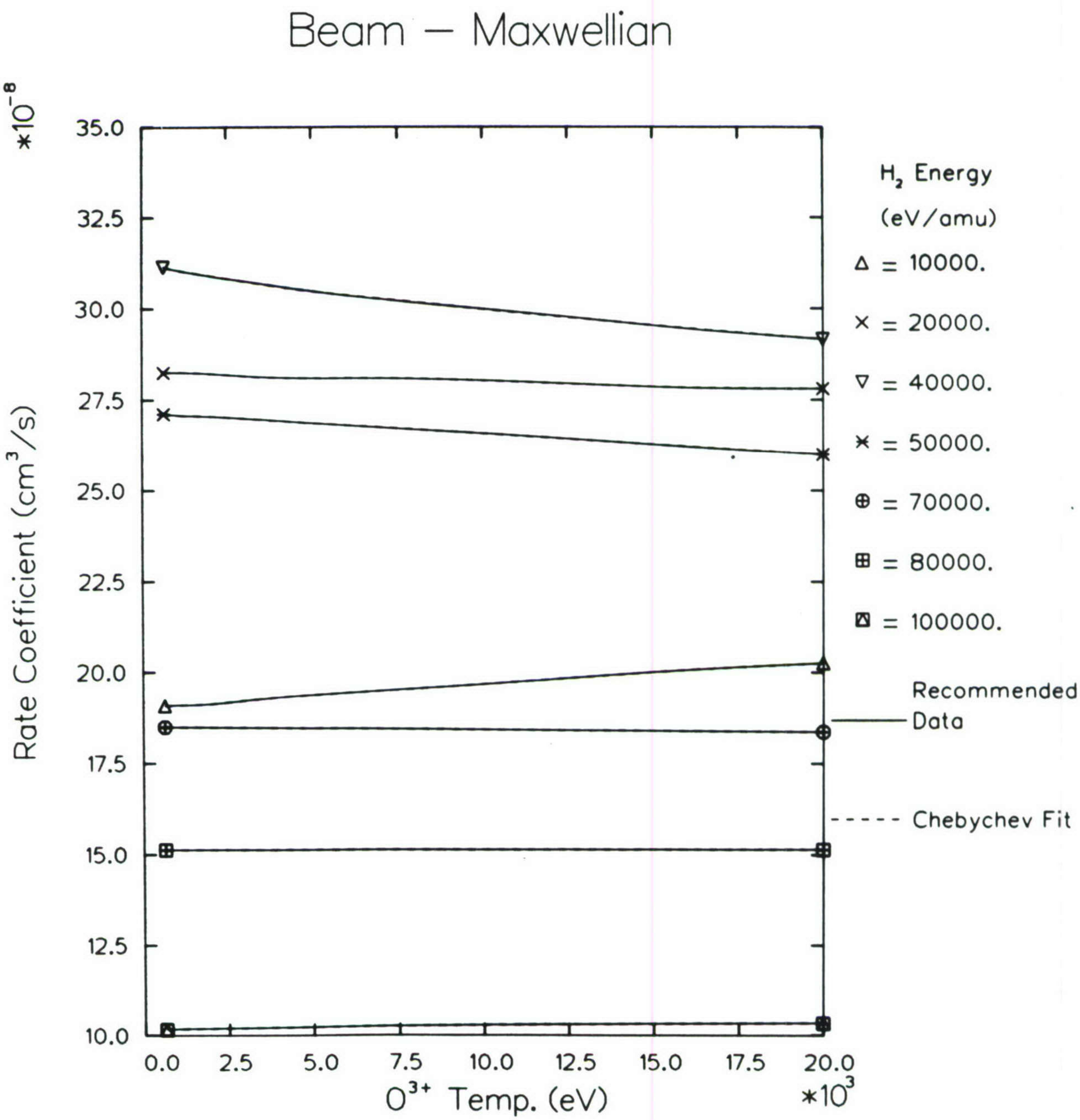
Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 6.4E+02 eV, E_{max} = 2.0E+04 eV

Chebychev Fitting Parameters for Rate Coefficients

H_2 Energy (eV/amu)	C1	C2	C3	C4	C5	C6	C7
10000.	3.893E-07	5.508E-09	2.148E-09	3.189E-10	6.877E-12	8.805E-11	-1.945E-10
20000.	5.617E-07	-2.196E-09	-7.816E-10	-1.071E-10	-1.281E-10	6.499E-11	2.721E-10
40000.	6.081E-07	-9.357E-09	-2.666E-09	-4.485E-10	-2.286E-11	-1.137E-10	9.766E-11
50000.	5.351E-07	-4.949E-09	-2.076E-09	-5.047E-10	-1.289E-11	-1.317E-10	8.658E-11
70000.	3.692E-07	-5.446E-10	-2.475E-10	-7.443E-11	8.870E-14	1.919E-11	-3.901E-11
80000.	3.027E-07	1.363E-10	2.629E-11	-2.467E-11	-2.942E-11	-1.488E-11	-5.878E-12
100000.	2.049E-07	9.250E-10	2.048E-10	-2.944E-11	-5.785E-11	-1.889E-11	7.880E-12

See appendix for Chebychev fit details.

$H_2 + O^{3+} \rightarrow O^{2+} + H_2^+$



Total Electron Capture Cross Sections for
$O^{4+} + H_2 \rightarrow O^{3+} + H_2^+$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
7.0E+01	1.16E+07	4.44E-15
1.0E+02	1.39E+07	4.07E-15
2.0E+02	1.96E+07	3.48E-15
4.0E+02	2.78E+07	3.08E-15
7.0E+02	3.68E+07	2.95E-15
1.0E+03	4.39E+07	3.00E-15
1.3E+03	4.91E+07	3.02E-15
2.0E+03	6.21E+07	3.08E-15
4.0E+03	8.79E+07	2.83E-15
7.0E+03	1.16E+08	2.59E-15
1.0E+04	1.39E+08	2.42E-15
2.0E+04	1.96E+08	2.03E-15
4.0E+04	2.78E+08	1.53E-15
7.0E+04	3.68E+08	9.25E-16
1.0E+05	4.39E+08	4.48E-16
1.4E+05	5.20E+08	1.45E-16

References: E.1, E.8, E.17, E.62

Accuracy: 25% for $E < 1\times10^3$ eV/amu; < 15% for $1\times10^3 \leq E$(eV/amu) $\leq 1\times10^4$; < 25% for $1\times10^4 <$ E(eV/amu) $< 4\times10^4$; < 20% for $E \geq 4\times10^4$ eV/amu

Note: The recommended cross-section between 1×10^4 and 4×10^4 eV/amu represents a smooth interpolation between the measurements of Refs. [E.62] and [E.8] and those of Ref. [E.1] at higher energies. An uncertainty of 25% has been assigned to this region.

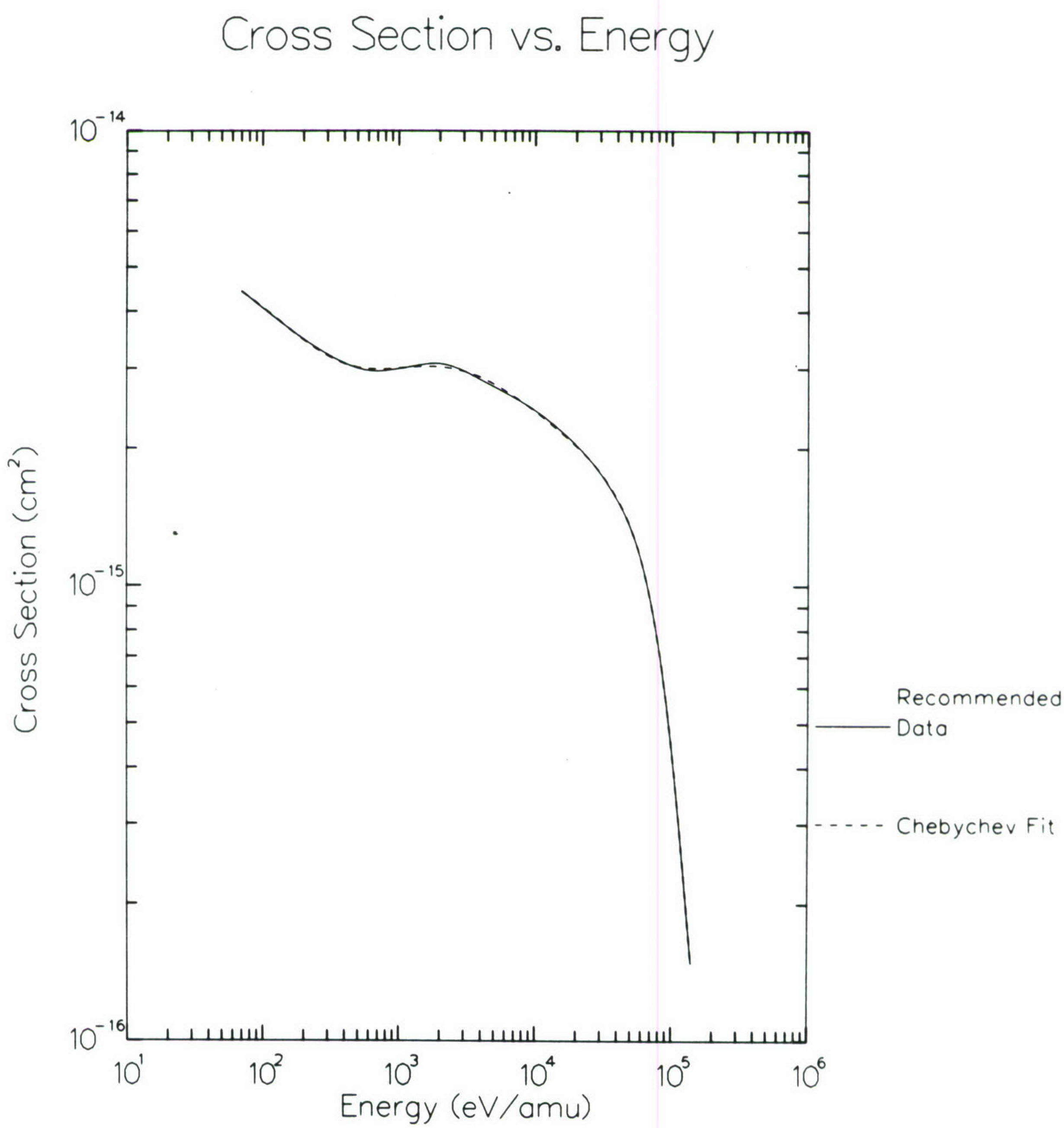
For Chebychev fits of the above cross sections it is necessary to use the following parameters.
E_{min} = 7.0E+01 eV/amu, E_{max} = 1.4E+05 eV/amu

Chebychev Fitting Parameters for Cross Sections

C1	C2	C3	C4	C5	C6	C7	C8	C9
4.958E-15	-1.830E-15	-2.860E-16	-3.693E-16	1.024E-16	7.114E-18	-4.333E-17	4.898E-17	3.668E-17

The fit represents the above cross sections with an rms deviation of 0.7%.
The maximum deviation is 1.3% at 4.0E+03 eV/amu.
See appendix for Chebychev fit details.

$O^{4+} + H_2 \rightarrow O^{3+} + H_2^+$



Total Electron Capture Rate Coefficients for
$O^{4+} + H_2 \rightarrow O^{3+} + H_2^+$

Maxwellian - Maxwellian Rate Coefficients (cm^3/s)

O^{4+} Temp. (eV)	Equal Temp.	H_2 Temp. (eV) 1.	10.	100.	1000.	5000.	10000.	20000.
1.1E+03	1.19E-07	3.61E-08*	3.80E-08*	5.27E-08*	1.14E-07	2.20E-07	2.78E-07	3.33E-07
1.6E+03	1.42E-07	4.72E-08*	4.86E-08*	5.97E-08*	1.17E-07	2.21E-07	2.79E-07	3.34E-07
3.2E+03	1.92E-07	6.91E-08	6.98E-08	7.68E-08	1.26E-07	2.24E-07	2.80E-07	3.34E-07
6.4E+03	2.49E-07	9.60E-08	9.66E-08	1.02E-07	1.42E-07	2.30E-07	2.84E-07	3.35E-07
1.1E+04	2.97E-07	1.26E-07	1.26E-07	1.30E-07	1.61E-07	2.39E-07	2.88E-07	3.37E-07
1.6E+04	3.25E-07	1.49E-07	1.49E-07	1.52E-07	1.78E-07	2.46E-07	2.93E-07	3.39E-07
2.0E+04	3.41E-07	1.64E-07	1.65E-07	1.67E-07	1.89E-07	2.52E-07	2.96E-07	3.41E-07

Accuracy: * - Possible Error Greater Than 10%
** - Possible Error Greater Than 100%

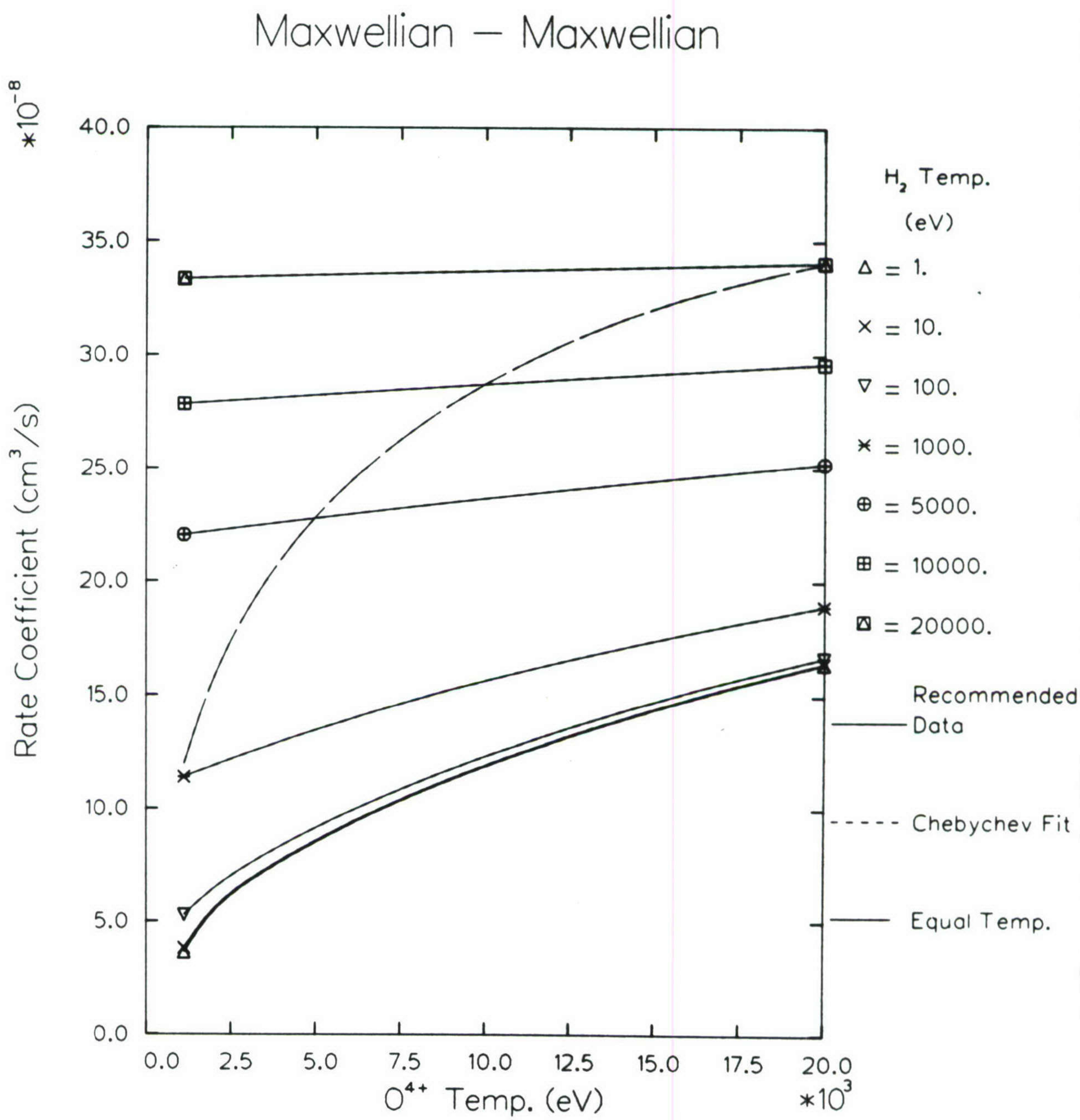
Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.1E+03 eV, E_{max} = 2.0E+04 eV

Chebychev Fitting Parameters for Rate Coefficients

H_2 Temp. (eV)	C1	C2	C3	C4	C5	C6	C7
1.	1.840E-07	6.254E-08	8.452E-09	1.688E-09	-3.403E-10	-1.387E-10	3.850E-11
10.	1.857E-07	6.179E-08	8.709E-09	1.588E-09	-3.207E-10	-1.349E-10	3.644E-11
100.	1.999E-07	5.624E-08	1.016E-08	1.044E-09	-2.283E-10	-9.888E-11	2.273E-11
1000.	2.854E-07	3.687E-08	9.041E-09	9.666E-10	-6.623E-11	-3.193E-11	8.071E-13
5000.	4.634E-07	1.517E-08	4.483E-09	8.010E-10	7.405E-11	-3.496E-12	-2.936E-12
10000.	5.691E-07	8.438E-09	2.597E-09	5.067E-10	6.033E-11	1.617E-12	-1.766E-12
20000.	6.717E-07	3.413E-09	1.055E-09	2.070E-10	2.476E-11	5.658E-13	-8.855E-13
Equal Temp.	4.545E-07	1.132E-07	3.388E-09	-2.503E-09	-6.281E-10	-1.928E-10	2.257E-11

See appendix for Chebychev fit details.

$O^{4+} + H_2 \rightarrow O^{3+} + H_2^+$



Total Electron Capture Rate Coefficients for
$H_2 + O^{4+} \rightarrow O^{3+} + H_2^+$

Beam - Maxwellian Rate Coefficients (cm^3/s)

O^{4+} Temp. (eV)	H_2 Energy (eV/amu) 10000.	20000.	40000.	50000.	70000.	80000.	100000.
1.1E+03	3.36E-07	3.98E-07	4.23E-07	4.00E-07	3.37E-07	2.87E-07	1.96E-07
1.6E+03	3.36E-07	3.98E-07	4.22E-07	4.00E-07	3.36E-07	2.87E-07	1.96E-07
3.2E+03	3.37E-07	3.97E-07	4.21E-07	3.99E-07	3.34E-07	2.86E-07	1.96E-07
6.4E+03	3.37E-07	3.97E-07	4.18E-07	3.97E-07	3.31E-07	2.85E-07	1.95E-07
1.1E+04	3.39E-07	3.97E-07	4.15E-07	3.95E-07	3.27E-07	2.83E-07	1.95E-07
1.6E+04	3.40E-07	3.95E-07	4.12E-07	3.92E-07	3.24E-07	2.80E-07	1.94E-07
2.0E+04	3.40E-07	3.96E-07	4.10E-07	3.90E-07	3.22E-07	2.78E-07	1.93E-07

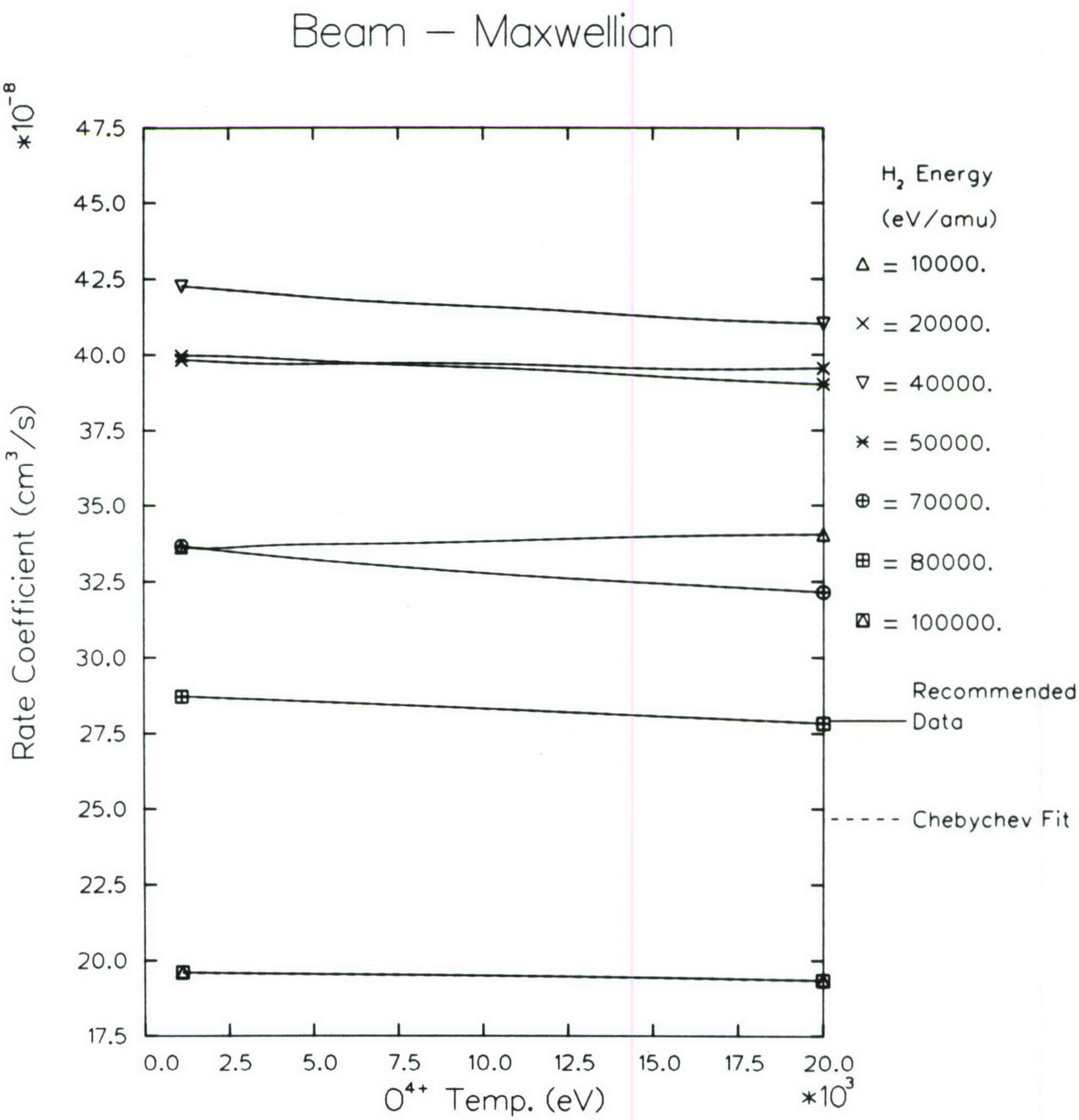
Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.1E+03 eV, E_{max} = 2.0E+04 eV

Chebychev Fitting Parameters for Rate Coefficients

H_2 Energy (eV/amu)	C1	C2	C3	C4	C5	C6	C7
10000.	6.752E-07	2.244E-09	7.288E-10	1.990E-11	1.225E-10	-1.736E-10	-9.093E-11
20000.	7.939E-07	-1.462E-09	-2.203E-10	-2.007E-10	-9.064E-11	2.980E-10	2.782E-10
40000.	8.355E-07	-6.102E-09	-1.523E-09	-2.258E-11	-2.454E-10	-4.478E-11	4.013E-10
50000.	7.933E-07	-4.424E-09	-1.689E-09	-1.999E-10	-2.777E-10	-4.671E-11	2.432E-10
70000.	6.615E-07	-7.337E-09	-1.606E-09	-2.385E-10	6.847E-11	-7.257E-12	-1.348E-10
80000.	5.687E-07	-4.010E-09	-1.511E-09	-3.653E-10	-5.926E-11	-9.997E-12	-1.063E-11
100000.	3.904E-07	-1.127E-09	-3.193E-10	-1.926E-10	-7.874E-11	2.768E-12	-1.520E-11

See appendix for Chebychev fit details.

$H_2 + O^{4+} \rightarrow O^{3+} + H_2^+$



Total Electron Capture Cross Sections for
$O^{5+} + H_2 \rightarrow O^{4+} + H_2^{+}$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
7.0E+01	1.16E+07	2.13E-15
1.0E+02	1.39E+07	2.01E-15
2.0E+02	1.96E+07	1.95E-15
4.0E+02	2.78E+07	1.89E-15
7.0E+02	3.68E+07	1.88E-15
1.0E+03	4.39E+07	1.90E-15
1.3E+03	4.91E+07	2.01E-15
2.0E+03	6.21E+07	2.10E-15
4.0E+03	8.79E+07	2.23E-15
7.0E+03	1.16E+08	2.50E-15
1.0E+04	1.39E+08	2.79E-15
2.0E+04	1.96E+08	3.27E-15
4.0E+04	2.78E+08	2.72E-15
7.0E+04	3.68E+08	1.65E-15
1.0E+05	4.39E+08	7.42E-16
2.0E+05	6.21E+08	1.02E-16
4.0E+05	8.78E+08	6.53E-18
7.0E+05	1.16E+09	4.68E-19
1.0E+06	1.39E+09	1.39E-19

References: E.1, E.7, E.17, E.18, E.62, E.63

Accuracy: 20% for $E \leq 1x10^3$ eV/amu; < 15% for $1x10^3 \leq E(eV/amu) \leq 1x10^4$; < 40% for $1x10^4 < E(eV/amu) < 5x10^4$; < 20% for $5x10^4 \leq E(eV/amu) \leq 2x10^5$; < 40% for $E > 2x10^5$ eV/amu

Notes: (1) In the energy regions $1x10^4 \leq E(eV/amu) \leq 5x10^4$, and $E \geq 1.2x10^5$ eV/amu, the cross section has been determined by the scaling relation for $\sigma(H_2)/\sigma(H)$ of Ref. [E.18] and by normalizing the results to the experimental data of Refs. [E.1] and [E.17] in the region between $5x10^4$ eV/amu and $1.2x10^5$ eV/amu (see sect. 1.1.4).
(2) In the energy region below ~ $5x10^4$ eV/amu both n = 3 and n = 4 shells of O^{4+} are expected to be populated in the reaction, with n = 4 becoming more important with decreasing energy.

For Chebychev fits of the above cross sections it is necessary to use the following parameters.
E_{min} = 7.0E+01 eV/amu, E_{max} = 1.0E+06 eV/amu

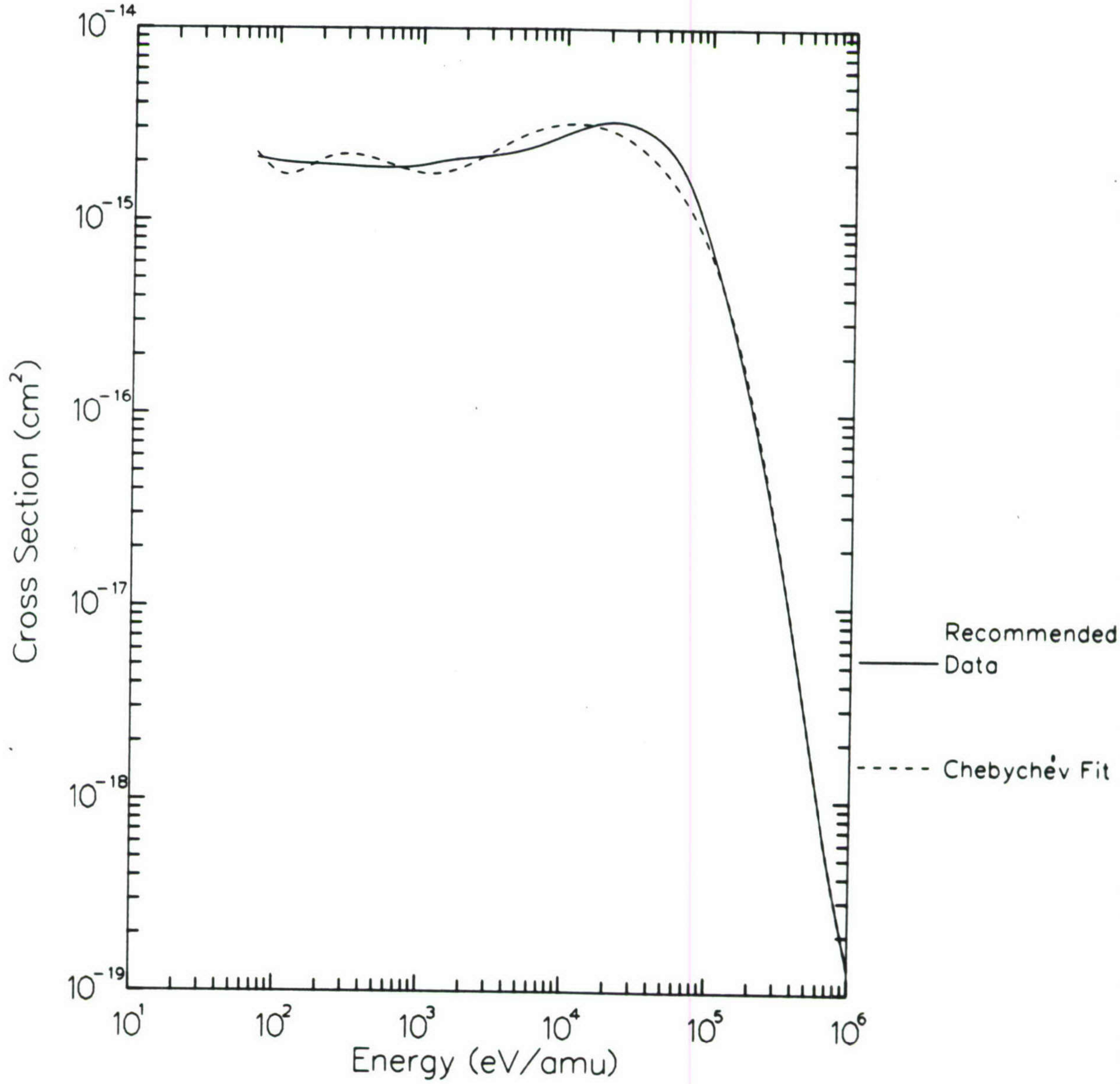
Chebychev Fitting Parameters for Cross Sections

C1	C2	C3	C4	C5	C6	C7	C8	C9
2.895E-15	-1.068E-15	-7.906E-16	-4.169E-17	5.006E-16	2.322E-16	-1.865E-16	-2.745E-16	1.814E-16

The fit represents the above cross sections with an rms deviation of 13.2%.
The maximum deviation is 20.3% at 7.0E+03 eV/amu.
See appendix for Chebychev fit details.

$$O^{5+} + H_2 \rightarrow O^{4+} + H_2^{+}$$

Cross Section vs. Energy



Total Electron Capture Rate Coefficients for
$O^{5+} + H_2 \rightarrow O^{4+} + H_2^+$

Maxwellian - Maxwellian Rate Coefficients (cm^3/s)

O^{5+} Temp. (eV)	Equal Temp.	H_2 Temp. (eV) 1.	10.	100.	1000.	5000.	10000.	20000.
1.1E+03	7.79E-08	1.91E-08*	2.03E-08*	2.94E-08*	7.35E-08	1.86E-07	2.96E-07	4.45E-07
1.6E+03	9.60E-08	2.59E-08*	2.68E-08*	3.41E-08	7.57E-08	1.87E-07	2.97E-07	4.46E-07
3.2E+03	1.47E-07	4.06E-08	4.11E-08	4.60E-08	8.28E-08	1.92E-07	3.01E-07	4.48E-07
6.4E+03	2.34E-07	6.00E-08	6.04E-08	6.41E-08	9.60E-08	2.01E-07	3.09E-07	4.52E-07
1.1E+04	3.41E-07	8.28E-08	8.31E-08	8.62E-08	1.14E-07	2.16E-07	3.20E-07	4.58E-07
1.6E+04	4.21E-07	1.02E-07	1.03E-07	1.05E-07	1.31E-07	2.29E-07	3.31E-07	4.64E-07
2.0E+04	4.69E-07	1.17E-07	1.17E-07	1.20E-07	1.44E-07	2.41E-07	3.39E-07	4.69E-07

Accuracy: * - Possible Error Greater Than 10%
** - Possible Error Greater Than 100%

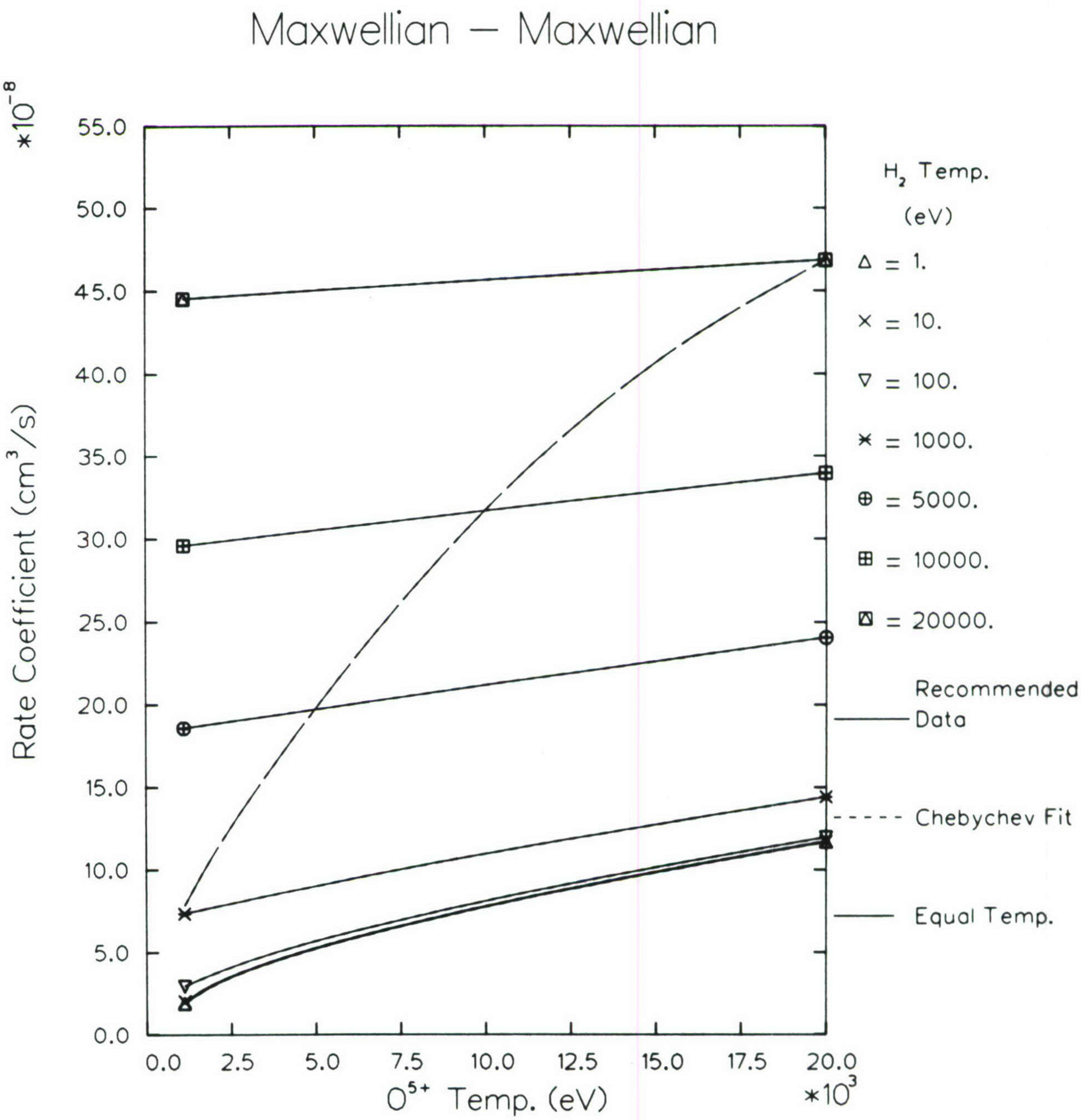
Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.1E+03 eV, E_{max} = 2.0E+04 eV

Chebychev Fitting Parameters for Rate Coefficients

H_2 Temp. (eV)	C1	C2	C3	C4	C5	C6	C7
1.	1.184E-07	4.696E-08	8.674E-09	1.963E-09	1.549E-10	-1.268E-11	3.760E-11
10.	1.195E-07	4.655E-08	8.812E-09	1.921E-09	1.607E-10	-9.355E-12	3.622E-11
100.	1.295E-07	4.345E-08	9.661E-09	1.699E-09	1.873E-10	1.630E-11	2.648E-11
1000.	1.976E-07	3.348E-08	9.782E-09	1.845E-09	2.615E-10	3.760E-11	6.497E-12
5000.	4.091E-07	2.564E-08	8.273E-09	1.779E-09	2.350E-10	7.818E-12	1.980E-11
10000.	6.220E-07	2.037E-08	6.568E-09	1.407E-09	2.358E-10	3.809E-12	-7.111E-11
20000.	9.067E-07	1.091E-08	3.435E-09	7.030E-10	9.419E-11	5.521E-12	-1.630E-12
Equal Temp.	4.695E-07	1.953E-07	4.161E-08	1.180E-09	-3.171E-09	-1.160E-09	-1.916E-11

See appendix for Chebychev fit details.

$O^{5+} + H_2 \rightarrow O^{4+} + H_2^+$



Total Electron Capture Rate Coefficients for
$H_2 + O^{5+} \rightarrow O^{4+} + H_2^+$

Beam - Maxwellian Rate Coefficients (cm^3/s)

O^{5+} Temp. (eV)	H_2 Energy (eV/amu) 10000.	20000.	40000.	70000.	100000.	200000.	500000.
1.1E+03	3.89E-07	6.39E-07	7.52E-07	6.00E-07	3.28E-07	6.34E-08	2.35E-09
1.6E+03	3.90E-07	6.38E-07	7.52E-07	5.98E-07	3.28E-07	6.34E-08	2.35E-09
3.2E+03	3.94E-07	6.35E-07	7.49E-07	5.94E-07	3.29E-07	6.35E-08	2.36E-09
6.4E+03	3.99E-07	6.34E-07	7.44E-07	5.88E-07	3.31E-07	6.38E-08	2.37E-09
1.1E+04	4.09E-07	6.32E-07	7.39E-07	5.80E-07	3.33E-07	6.42E-08	2.39E-09
1.6E+04	4.19E-07	6.29E-07	7.32E-07	5.74E-07	3.34E-07	6.47E-08	2.41E-09
2.0E+04	4.27E-07	6.30E-07	7.28E-07	5.69E-07	3.35E-07	6.51E-08	2.43E-09

Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.1E+03 eV, E_{max} = 2.0E+04 eV

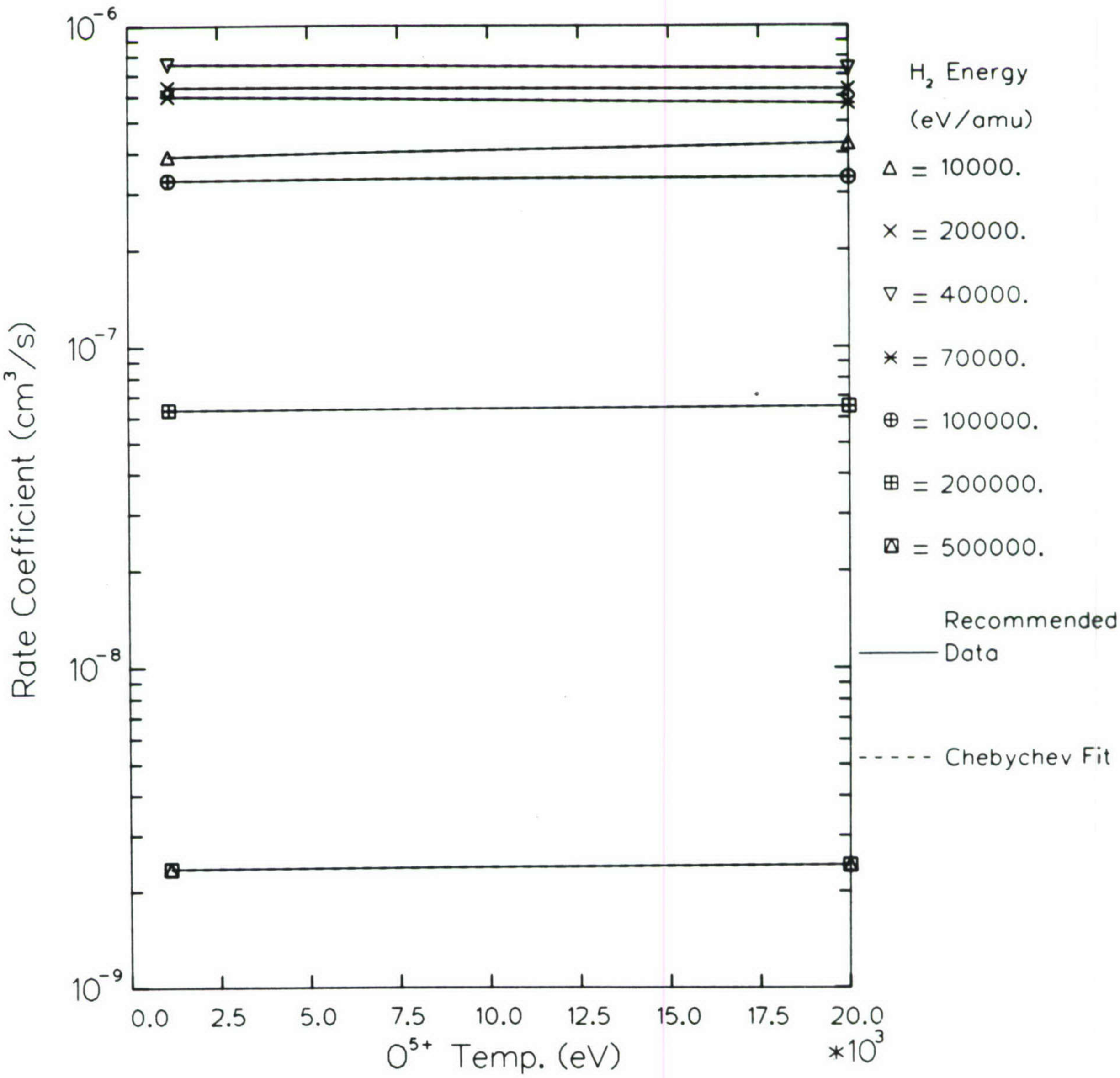
Chebychev Fitting Parameters for Rate Coefficients

H_2 Energy (eV/amu)	C1	C2	C3	C4	C5	C6	C7
10000.	8.041E-07	1.759E-08	6.100E-09	1.748E-09	1.403E-10	-2.233E-10	6.164E-11
20000.	1.269E-06	-4.554E-09	-3.218E-10	-2.539E-10	-1.347E-10	5.339E-10	5.029E-10
40000.	1.487E-06	-1.173E-08	-3.390E-09	-2.351E-10	-4.764E-10	-8.778E-11	7.143E-10
70000.	1.175E-06	-1.487E-08	-3.207E-09	-4.481E-10	1.263E-10	-5.910E-12	-2.262E-10
100000.	6.615E-07	3.600E-09	6.059E-10	-1.399E-10	-9.548E-11	1.108E-11	-3.990E-11
200000.	1.279E-07	7.762E-10	2.889E-10	7.669E-11	3.515E-12	-5.220E-12	8.462E-12
500000.	4.749E-09	3.622E-11	1.248E-11	3.075E-12	9.210E-13	1.080E-13	-4.737E-13

See appendix for Chebychev fit details.

$H_2 + O^{5+} \rightarrow O^{4+} + H_2^+$

Beam – Maxwellian



Total Electron Capture Cross Sections for
$O^{6+} + H_2 \rightarrow O^{5+} + H_2^+$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
1.0E+02	1.39E+07	5.36E-15
2.0E+02	1.96E+07	4.99E-15
4.0E+02	2.78E+07	4.72E-15
7.0E+02	3.68E+07	4.48E-15
1.0E+03	4.39E+07	4.31E-15
1.3E+03	4.91E+07	4.10E-15
2.0E+03	6.21E+07	4.02E-15
4.0E+03	8.79E+07	3.76E-15
7.0E+03	1.16E+08	3.64E-15
1.0E+04	1.39E+08	3.73E-15
2.0E+04	1.96E+08	4.13E-15
4.0E+04	2.78E+08	3.81E-15
7.0E+04	3.68E+08	2.24E-15
1.0E+05	4.39E+08	1.11E-15
2.0E+05	6.21E+08	1.55E-16
4.0E+05	8.78E+08	8.14E-18
7.0E+05	1.16E+09	5.30E-19
1.0E+06	1.39E+09	1.08E-19

References: E.7, E.8, E.9, E.17, E.18, E.19, E.35, E.54, E.62

Accuracy: 15% for $E \leq 1 \times 10^4$ eV/amu; < 40% for $1 \times 10^4 <$ E(eV/amu) $\leq 1 \times 10^5$; < 20% for $1 \times 10^5 \leq$ E(eV/amu) $\leq 2 \times 10^5$; < 40% for $E > 2 \times 10^5$ eV/amu

Notes: (1) In the energy region above 1×10^4 eV/amu, the cross section has been determined by using the data point at $E = 1.2 \times 10^5$ eV/amu of Ref. [E.17] (15% accuracy) and the scaling law for the $\sigma(H_2)/\sigma(H)$ ratio [E.18] (see sect. 1.1.4).
(2) There is evidence [E.35] that in the region $5 \times 10^2 \leq$ E(eV/amu) $\leq 8 \times 10^3$, the n = 4 shell of O^{5+} is predominantly populated, with 4p and 4s being preferentially populated over the lower part of this region, and 4f at the higher energies.

For Chebychev fits of the above cross sections it is necessary to use the following parameters.
E_{min} = 1.0E+02 eV/amu, E_{max} = 1.0E+06 eV/amu

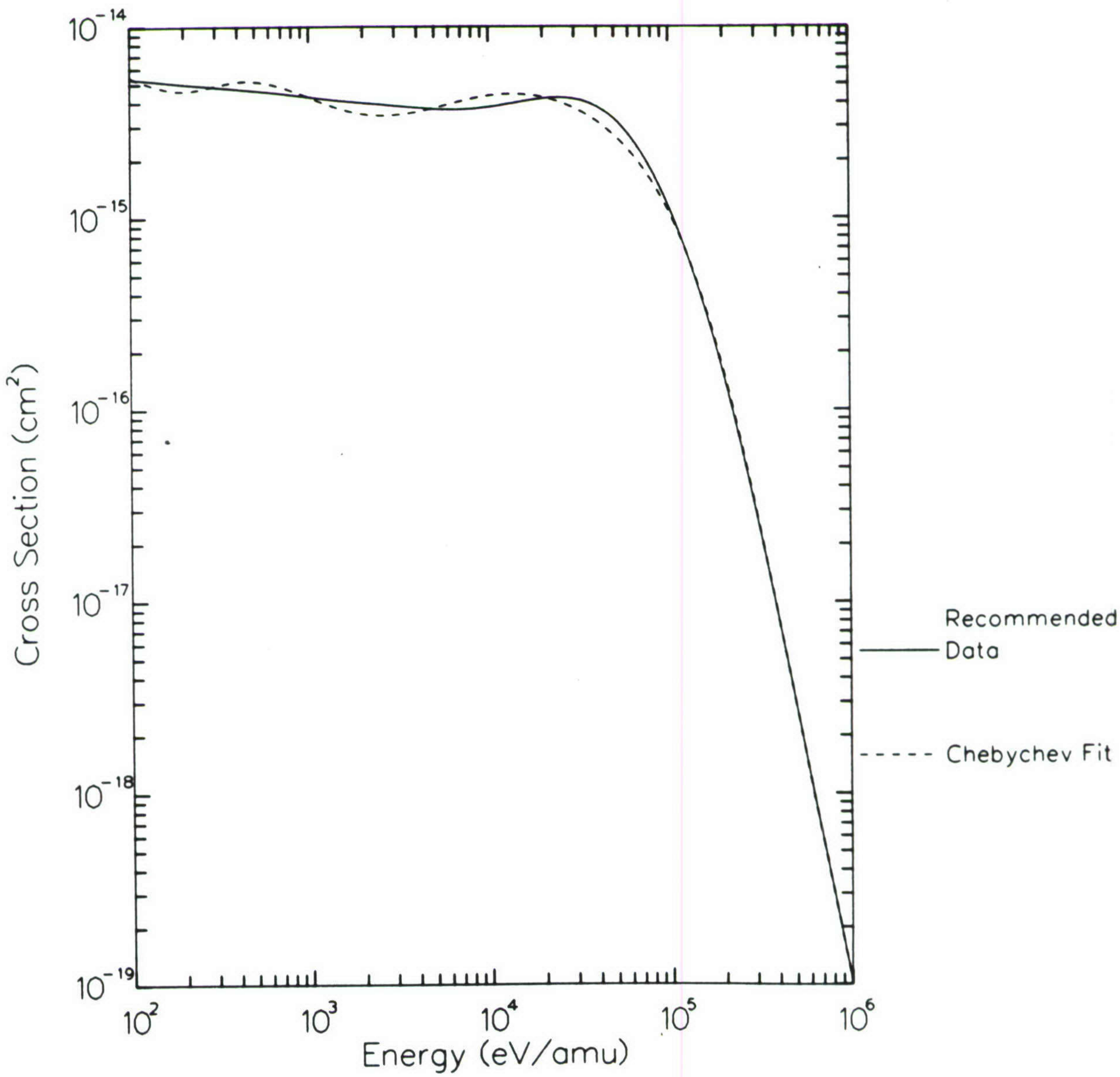
Chebychev Fitting Parameters for Cross Sections

C1	C2	C3	C4	C5	C6	C7	C8	C9
5.577E-15	-2.678E-15	-7.039E-16	1.438E-16	4.374E-16	3.401E-16	-8.979E-17	-5.578E-16	3.201E-16

The fit represents the above cross sections with an rms deviation of 9.8%.
The maximum deviation is 16.3% at 1.0E+04 eV/amu.
See appendix for Chebychev fit details.

$O^{6+} + H_2 \rightarrow O^{5+} + H_2^+$

Cross Section vs. Energy



Total Electron Capture Rate Coefficients for
$O^{6+} + H_2 \rightarrow O^{5+} + H_2^+$

Maxwellian - Maxwellian Rate Coefficients (cm3/s)

O^{6+} Temp. (eV)	Equal Temp.	H_2 Temp. (eV) 1.	10.	100.	1000.	5000.	10000.	20000.
1.6E+03	1.94E-07	5.75E-08*	5.98E-08*	7.96E-08*	1.64E-07	3.08E-07	4.30E-07	6.05E-07
3.2E+03	2.61E-07	9.59E-08*	9.72E-08*	1.09E-07	1.75E-07	3.13E-07	4.34E-07	6.07E-07
6.4E+03	3.60E-07	1.37E-07	1.38E-07	1.44E-07	1.94E-07	3.24E-07	4.43E-07	6.12E-07
1.1E+04	4.80E-07	1.75E-07	1.75E-07	1.80E-07	2.19E-07	3.39E-07	4.55E-07	6.20E-07
1.6E+04	5.74E-07	2.03E-07	2.04E-07	2.07E-07	2.41E-07	3.55E-07	4.68E-07	6.27E-07
2.0E+04	6.33E-07	2.23E-07	2.24E-07	2.27E-07	2.58E-07	3.67E-07	4.78E-07	6.33E-07

Accuracy: * - Possible Error Greater Than 10%
** - Possible Error Greater Than 100%

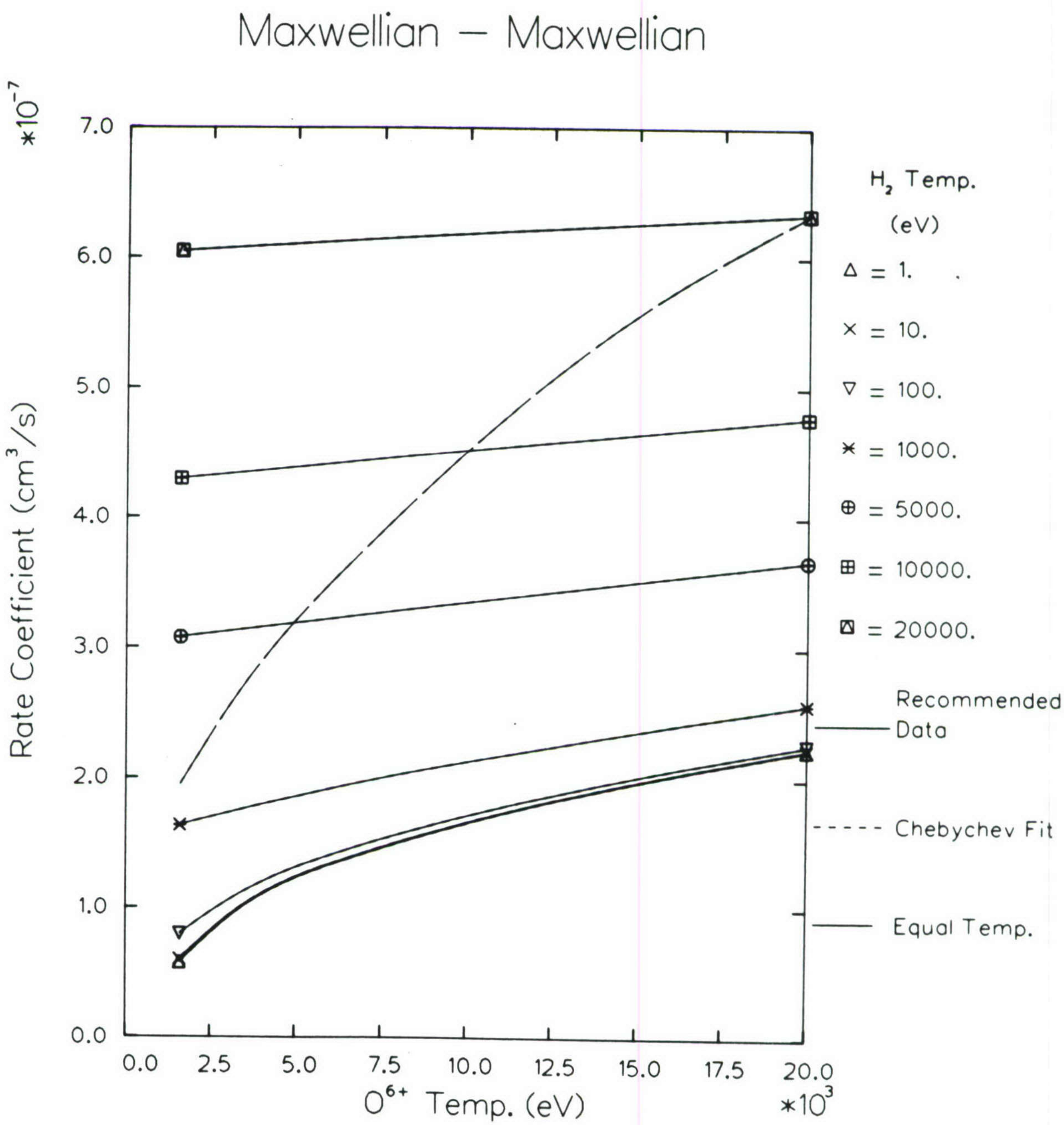
Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.6E+03 eV, E_{max} = 2.0E+04 eV

Chebychev Fitting Parameters for Rate Coefficients

H_2 Temp. (eV)	C1	C2	C3	C4	C5	C6	C7
1.	2.692E-07	8.145E-08	5.560E-09	1.456E-09	1.879E-10	-3.499E-11	
10.	2.713E-07	8.048E-08	5.855E-09	1.397E-09	1.901E-10	-3.287E-11	
100.	2.902E-07	7.261E-08	7.973E-09	1.055E-09	1.743E-10	-1.088E-11	
1000.	4.004E-07	4.573E-08	1.030E-08	1.293E-09	9.157E-11	2.907E-11	
5000.	6.582E-07	2.817E-08	7.995E-09	1.498E-09	1.971E-10	1.898E-11	
10000.	8.938E-07	2.279E-08	6.513E-09	1.227E-09	1.605E-10	1.148E-11	
20000.	1.230E-06	1.368E-08	3.847E-09	7.009E-10	8.608E-11	1.891E-12	
Equal Temp.	7.563E-07	2.185E-07	3.763E-08	2.162E-09	-1.991E-09	-1.203E-09	

See appendix for Chebychev fit details.

$O^{6+} + H_2 \rightarrow O^{5+} + H_2^+$



Total Electron Capture Rate Coefficients for
$H_2 + O^{6+} \rightarrow O^{5+} + H_2^+$

Beam - Maxwellian Rate Coefficients (cm^3/s)

O^{6+} Temp. (eV)	H_2 Energy (eV/amu) 10000.	20000.	40000.	70000.	100000.	200000.	500000.
1.6E+03	5.21E-07	8.08E-07	1.04E-06	8.17E-07	4.89E-07	9.64E-08	2.80E-09
3.2E+03	5.26E-07	8.05E-07	1.04E-06	8.14E-07	4.89E-07	9.66E-08	2.81E-09
6.4E+03	5.34E-07	8.07E-07	1.03E-06	8.08E-07	4.90E-07	9.70E-08	2.83E-09
1.1E+04	5.47E-07	8.09E-07	1.02E-06	8.01E-07	4.91E-07	9.77E-08	2.85E-09
1.6E+04	5.59E-07	8.09E-07	1.01E-06	7.95E-07	4.91E-07	9.85E-08	2.88E-09
2.0E+04	5.67E-07	8.13E-07	1.00E-06	7.90E-07	4.91E-07	9.91E-08	2.90E-09

Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.6E+03 eV, E_{max} = 2.0E+04 eV

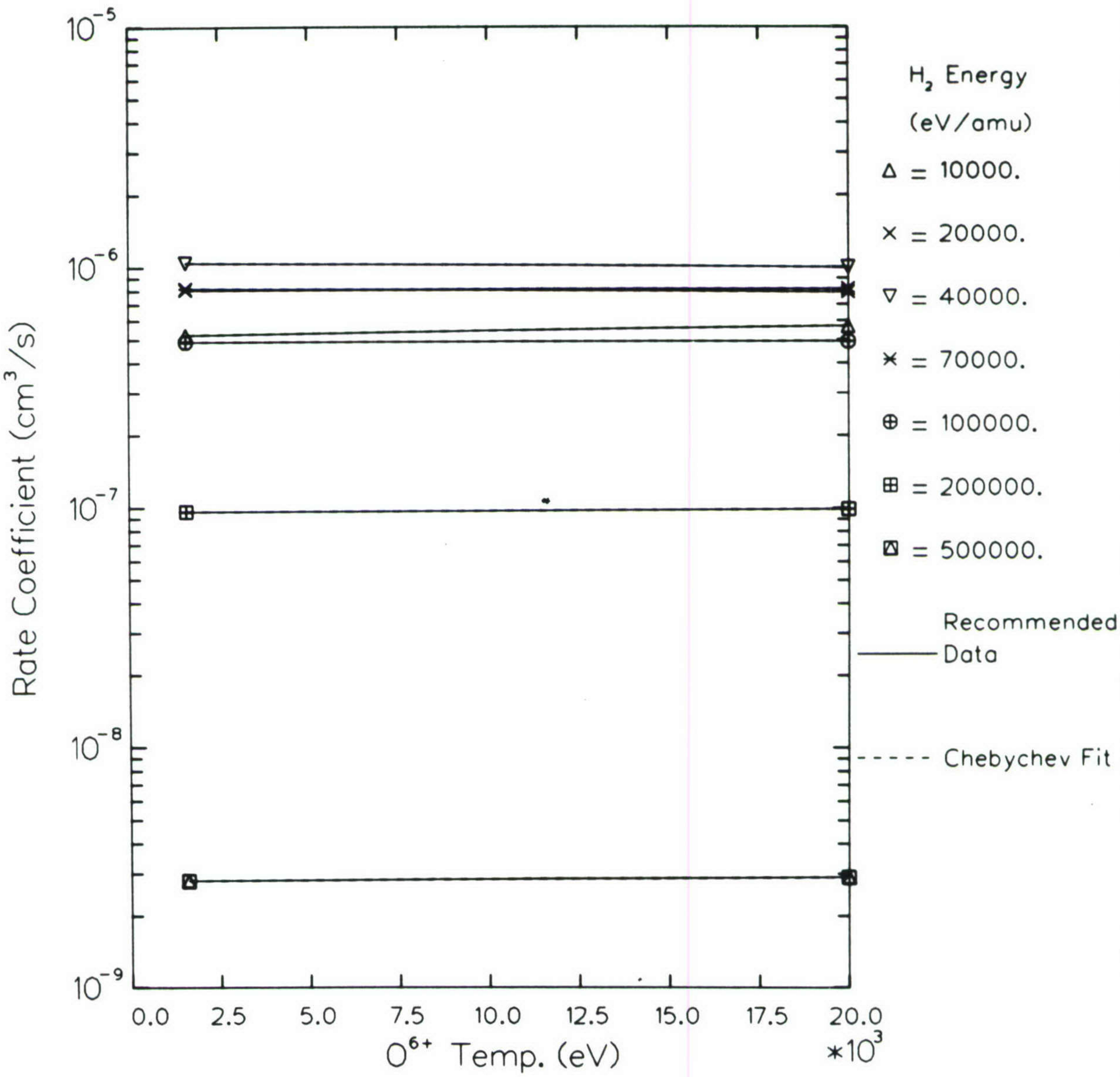
Chebychev Fitting Parameters for Rate Coefficients

H_2 Energy (eV/amu)	C1	C2	C3	C4	C5	C6	C7
10000.	1.076E-06	2.259E-08	5.639E-09	9.923E-10	1.555E-10	-5.775E-10	
20000.	1.617E-06	1.550E-09	2.207E-09	-1.503E-10	-3.004E-10	1.564E-09	
40000.	2.056E-06	-2.342E-08	-4.283E-09	-1.882E-11	-1.678E-09	1.648E-09	
70000.	1.613E-06	-1.283E-08	-3.262E-09	-3.304E-10	4.448E-10	-5.896E-10	
100000.	9.795E-07	1.426E-09	-5.772E-11	-2.971E-10	5.361E-12	-8.654E-11	
200000.	1.946E-07	1.234E-09	4.245E-10	8.909E-11	-1.492E-11	1.685E-11	
500000.	5.674E-09	4.883E-11	1.432E-11	3.405E-12	1.364E-12	-8.365E-13	

See appendix for Chebychev fit details.

$H_2 + O^{6+} \rightarrow O^{5+} + H_2^+$

Beam – Maxwellian



Total Electron Capture Cross Sections for
$O^{7+} + H_2 \rightarrow O^{6+} + H_2^+$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
1.6E+02	1.76E+07	1.27E-15
2.0E+02	1.96E+07	1.43E-15
4.0E+02	2.78E+07	1.89E-15
7.0E+02	3.68E+07	2.37E-15
1.0E+03	4.39E+07	2.74E-15
1.3E+03	4.91E+07	3.00E-15
2.0E+03	6.21E+07	3.33E-15
4.0E+03	8.79E+07	3.85E-15
7.0E+03	1.16E+08	4.18E-15
1.0E+04	1.39E+08	4.40E-15
2.0E+04	1.96E+08	4.59E-15
4.0E+04	2.78E+08	4.11E-15
7.0E+04	3.68E+08	2.68E-15
1.0E+05	4.39E+08	1.46E-15
2.0E+05	6.21E+08	2.07E-16
4.0E+05	8.78E+08	1.62E-17
7.0E+05	1.16E+09	1.65E-18
1.0E+06	1.39E+09	3.31E-19

References: E.9, E.11, E.17, E.18, E.54

Accuracy: 15% for $E \leq 8x10^3$ eV/amu; 50% for $8x10^3 <$ E(eV/amu) $< 1x10^5$; 20% for $1x10^5 \leq$ E(eV/amu) $\leq 2x10^5$; 40% for $E > 2x10^5$ eV/amu

Notes: (1) The cross section in the region $E \geq 1x10^4$ eV/amu has been constructed by using the scaling ratio $\sigma(H_2)/\sigma(H)$ of Ref. [E.18] and normalizing the results to the data point of Ref. [E.17] at $E = 1.2x10^5$ eV/amu (having in estimated accuracy of ~ 15%).
(2) In the region below ~ $5x10^4$ eV/amu, capture to n = 5 shell of O^{6+} is expected to be dominant.

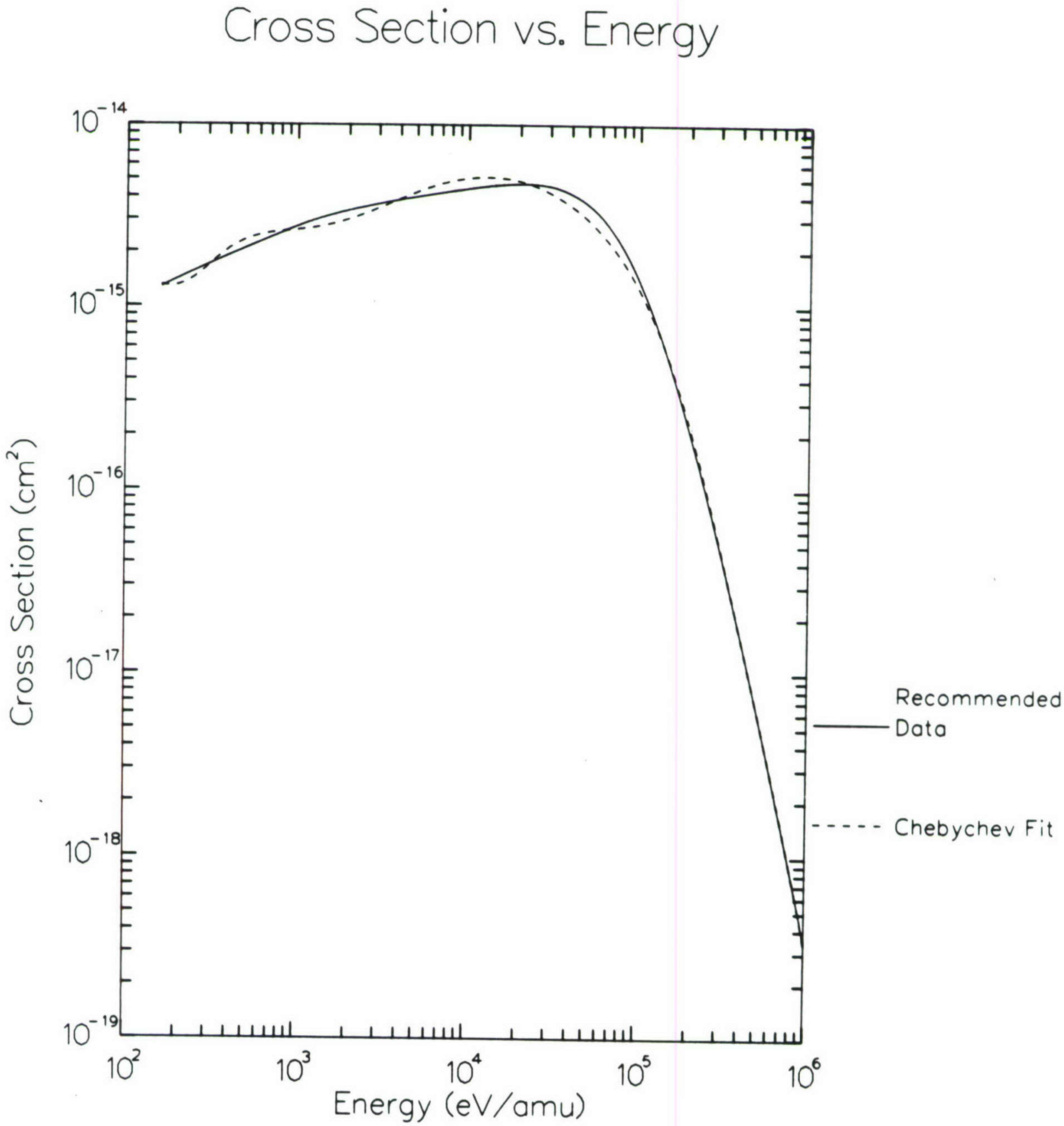
For Chebychev fits of the above cross sections it is necessary to use the following parameters.
E_{min} = 1.6E+02 eV/amu, E_{max} = 1.0E+06 eV/amu

Chebychev Fitting Parameters for Cross Sections

C1	C2	C3	C4	C5	C6	C7	C8	C9
3.740E-15	-9.856E-16	-1.825E-15	3.467E-16	8.240E-16	1.569E-16	-3.902E-16	-1.975E-16	2.008E-16

The fit represents the above cross sections with an rms deviation of 10.5%.
The maximum deviation is 14.5% at 1.0E+04 eV/amu.
See appendix for Chebychev fit details.

$O^{7+} + H_2 \rightarrow O^{6+} + H_2^+$



Total Electron Capture Rate Coefficients for
$O^{7+} + H_2 \rightarrow O^{6+} + H_2^+$

Maxwellian - Maxwellian Rate Coefficients (cm^3/s)

O^{7+} Temp. (eV)	Equal Temp.	H_2 Temp. (eV) 1.	10.	100.	1000.	5000.	10000.	20000.
2.6E+03	2.00E-07	2.70E-08*	2.80E-08*	3.71E-08*	1.10E-07	3.07E-07	4.69E-07	6.73E-07
3.2E+03	2.35E-07	3.52E-08*	3.61E-08*	4.48E-08	1.15E-07	3.10E-07	4.71E-07	6.74E-07
6.4E+03	3.74E-07	7.10E-08	7.17E-08	7.89E-08	1.41E-07	3.25E-07	4.81E-07	6.80E-07
1.1E+04	5.26E-07	1.15E-07	1.16E-07	1.22E-07	1.75E-07	3.47E-07	4.97E-07	6.89E-07
1.6E+04	6.36E-07	1.53E-07	1.53E-07	1.58E-07	2.06E-07	3.68E-07	5.12E-07	6.97E-07
2.0E+04	7.04E-07	1.80E-07	1.81E-07	1.86E-07	2.30E-07	3.84E-07	5.24E-07	7.04E-07

Accuracy: * - Possible Error Greater Than 10%
** - Possible Error Greater Than 100%

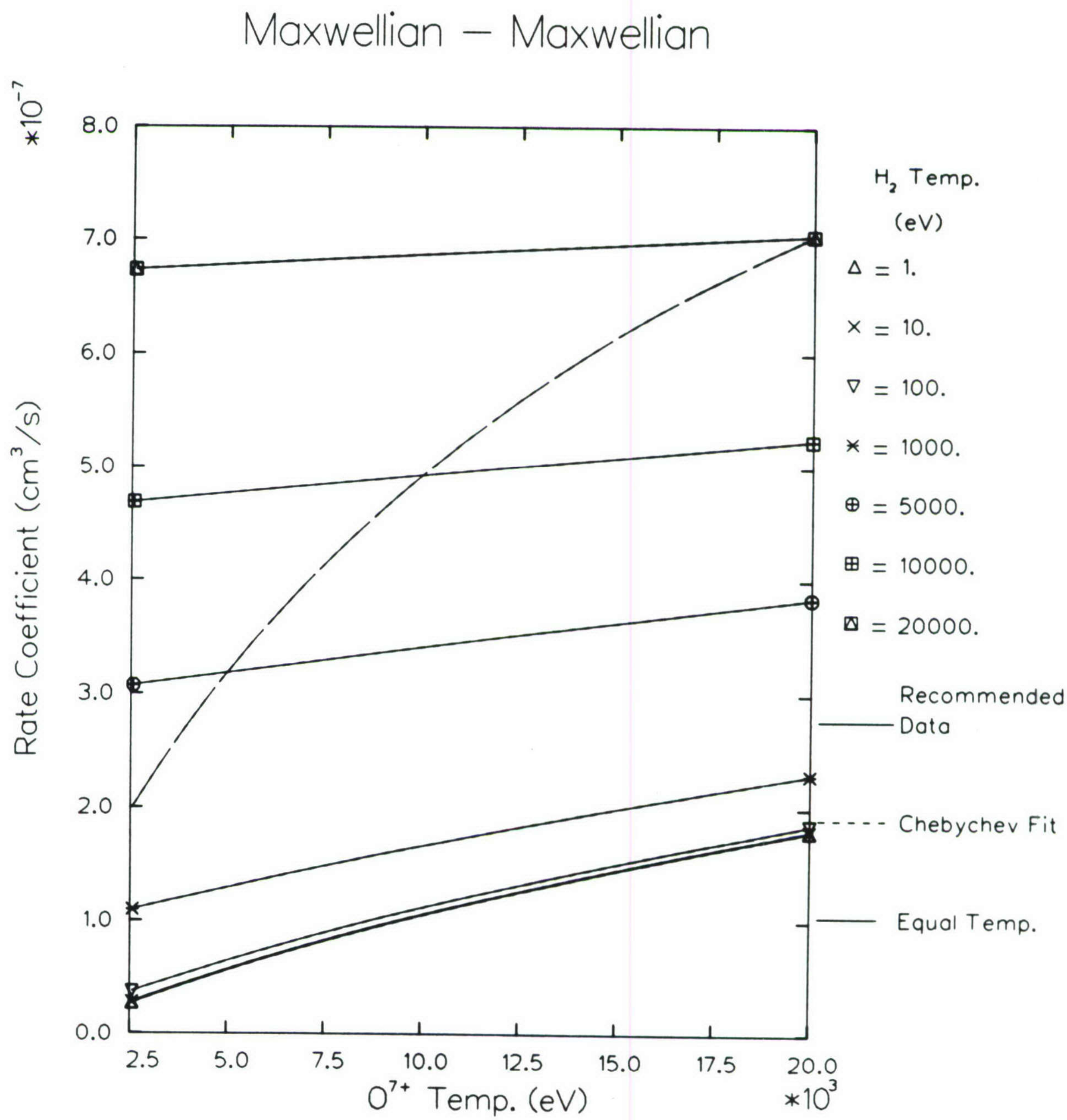
Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 2.6E+03 eV, E_{max} = 2.0E+04 eV

Chebychev Fitting Parameters for Rate Coefficients

H_2 Temp. (eV)	C1	C2	C3	C4	C5	C6	C7
1.	1.821E-07	7.556E-08	1.258E-08	1.126E-09	5.859E-11	1.349E-11	
10.	1.836E-07	7.533E-08	1.258E-08	1.128E-09	5.931E-11	1.311E-11	
100.	1.974E-07	7.313E-08	1.259E-08	1.154E-09	6.492E-11	9.536E-12	
1000.	3.159E-07	5.887E-08	1.180E-08	1.344E-09	7.503E-11	-2.476E-12	
5000.	6.742E-07	3.749E-08	8.491E-09	1.132E-09	7.635E-11	2.017E-11	
10000.	9.800E-07	2.683E-08	6.293E-09	1.010E-09	3.585E-11	-8.676E-11	
20000.	1.370E-06	1.478E-08	3.486E-09	5.572E-10	1.308E-10	6.591E-11	
Equal Temp.	8.568E-07	2.546E-07	2.498E-08	-2.444E-09	-1.402E-09	-2.654E-10	

See appendix for Chebychev fit details.

$O^{7+} + H_2 \rightarrow O^{6+} + H_2^+$



Total Electron Capture Rate Coefficients for
$H_2 + O^{7+} \rightarrow O^{6+} + H_2^+$

Beam - Maxwellian Rate Coefficients (cm^3/s)

O^{7+} Temp. (eV)	H_2 Energy (eV/amu) 10000.	20000.	40000.	70000.	100000.	200000.	500000.
2.6E+03	6.16E-07	9.00E-07	1.13E-06	9.73E-07	6.41E-07	1.30E-07	6.58E-09
3.2E+03	6.17E-07	8.99E-07	1.13E-06	9.72E-07	6.40E-07	1.30E-07	6.58E-09
6.4E+03	6.22E-07	9.01E-07	1.12E-06	9.65E-07	6.40E-07	1.31E-07	6.61E-09
1.1E+04	6.32E-07	9.03E-07	1.11E-06	9.55E-07	6.39E-07	1.32E-07	6.65E-09
1.6E+04	6.43E-07	9.02E-07	1.10E-06	9.48E-07	6.37E-07	1.34E-07	6.69E-09
2.0E+04	6.52E-07	9.06E-07	1.10E-06	9.41E-07	6.37E-07	1.35E-07	6.72E-09

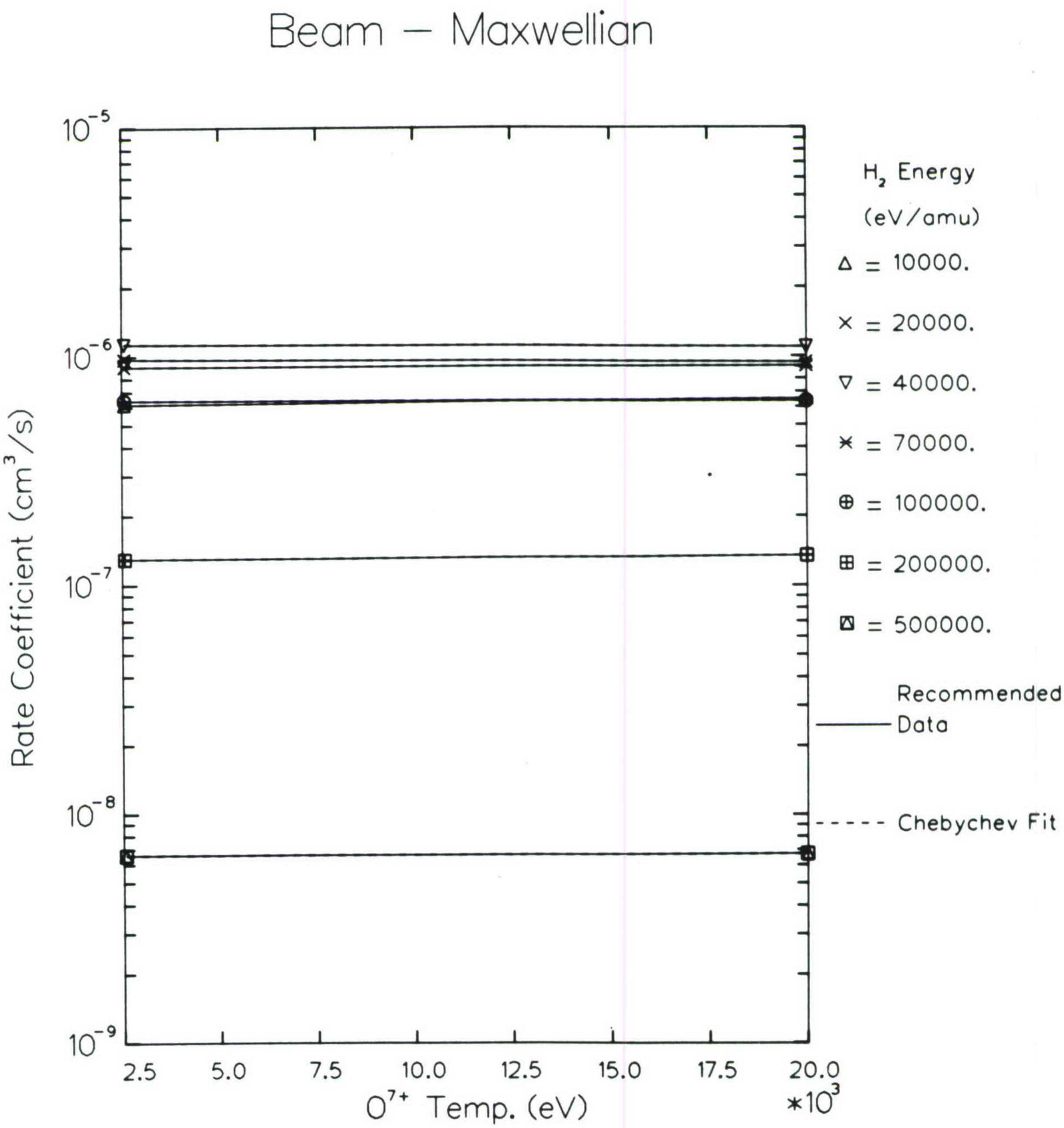
Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 2.6E+03 eV, E_{max} = 2.0E+04 eV

Chebychev Fitting Parameters for Rate Coefficients

H_2 Energy (eV/amu)	C1	C2	C3	C4	C5	C6	C7
10000.	1.257E-06	1.672E-08	5.226E-09	9.595E-10	-1.525E-10	4.456E-11	
20000.	1.803E-06	2.729E-09	6.377E-10	-4.602E-10	1.076E-09	6.816E-10	
40000.	2.232E-06	-1.627E-08	-2.249E-09	-9.594E-10	1.875E-10	9.137E-10	
70000.	1.921E-06	-1.589E-08	-3.124E-09	4.055E-10	-3.696E-10	-2.794E-10	
100000.	1.278E-06	-1.907E-09	-6.358E-10	-2.038E-10	2.108E-10	1.005E-10	
200000.	2.633E-07	2.331E-09	5.278E-10	5.944E-11	-1.629E-12	1.248E-11	
500000.	1.326E-08	7.055E-11	1.846E-11	4.798E-12	1.489E-13	-1.134E-12	

See appendix for Chebychev fit details.

$H_2 + O^{7+} \rightarrow O^{6+} + H_2^+$



Total Electron Capture Cross Sections for
$O^{8+} + H_2 \rightarrow O^{7+} + H_2^+$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
1.7E+02	1.81E+07	2.95E-15
2.0E+02	1.96E+07	3.65E-15
4.0E+02	2.78E+07	4.92E-15
7.0E+02	3.68E+07	5.23E-15
1.0E+03	4.39E+07	5.25E-15
1.3E+03	4.91E+07	5.10E-15
2.0E+03	6.21E+07	5.00E-15
4.0E+03	8.79E+07	4.88E-15
7.0E+03	1.16E+08	4.87E-15
1.0E+04	1.39E+08	4.87E-15
2.0E+04	1.96E+08	4.90E-15
4.0E+04	2.78E+08	4.84E-15
7.0E+04	3.68E+08	4.01E-15
1.0E+05	4.39E+08	2.60E-15
2.0E+05	6.21E+08	2.57E-16
2.7E+05	7.22E+08	8.58E-17

References: E.11, E.18, E.64, T.49, T.50

Accuracy: 15% for $E \leq 1x10^4$ eV/amu; 100% for $E > 1x10^4$ eV/amu

Notes: (1) There are no cross-section data for $E > 1x10^4$ eV/amu. This portion of the cross-section curve was constructed by using the scaling ratio for $\sigma(H_2)/\sigma(H)$ of Ref. [E.18], reducing the results by the same factor used in the case of $O^{7+} + H_2$, where experimental data were available for normalization. The accuracy for $E \geq 1.5x10^5$ eV/amu is estimated to be better than 100%.
(2) The n = 5 shell of O^{7+} is expected to be most populated for $E \leq 2x10^4$ eV/amu.

For Chebychev fits of the above cross sections it is necessary to use the following parameters.
E_{min} = 1.7E+02 eV/amu, E_{max} = 2.7E+05 eV/amu

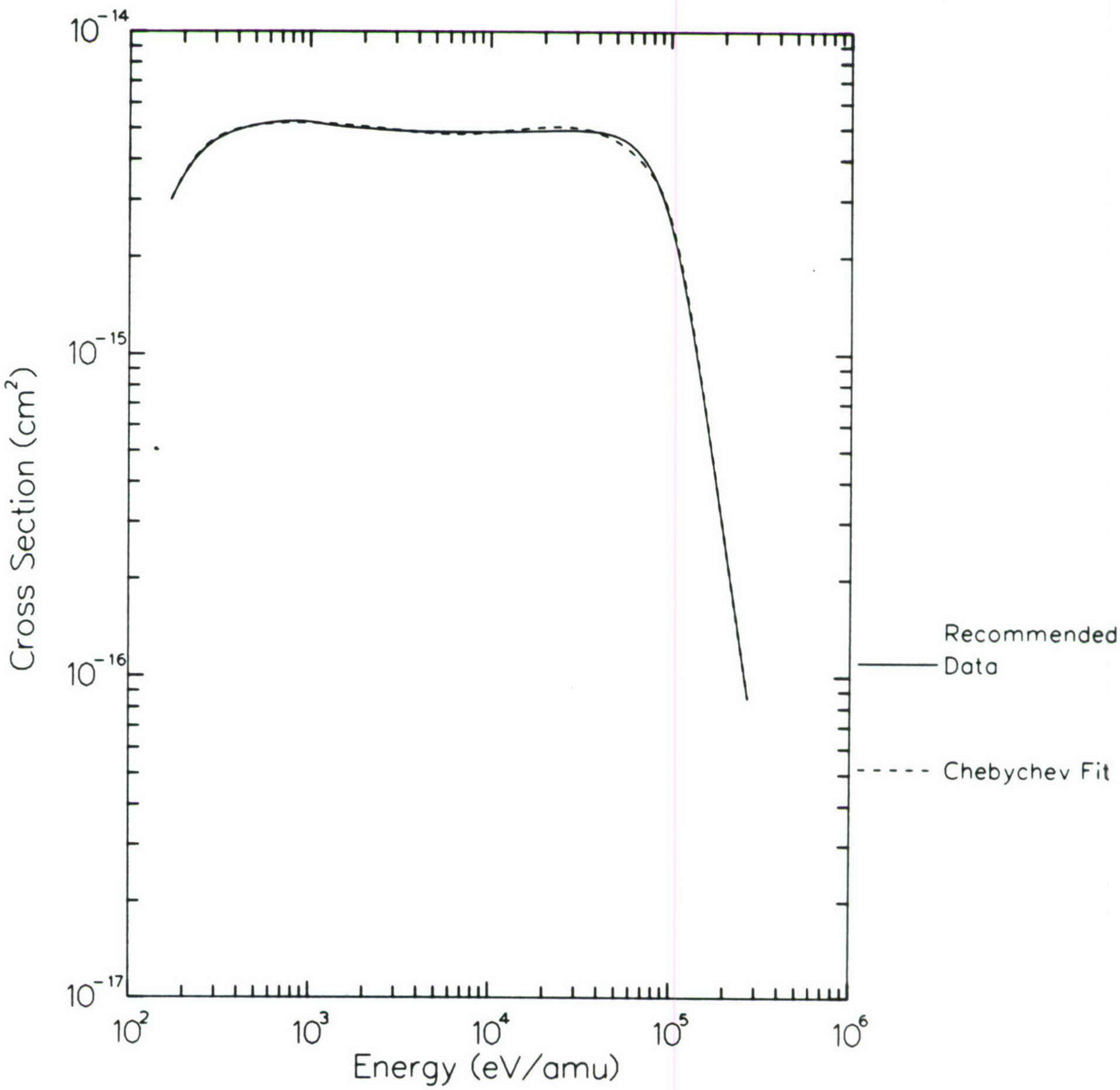
Chebychev Fitting Parameters for Cross Sections

C1	C2	C3	C4	C5	C6	C7	C8	C9
7.194E-15	-1.616E-15	-1.864E-15	-3.349E-16	-4.384E-16	3.601E-16	2.217E-16	1.581E-16	2.306E-18

The fit represents the above cross sections with an rms deviation of 1.7%.
The maximum deviation is 3.2% at 1.0E+05 eV/amu.
See appendix for Chebychev fit details.

$O^{8+} + H_2 \rightarrow O^{7+} + H_2^+$

Cross Section vs. Energy



Total Electron Capture Rate Coefficients for
$O^{8+} + H_2 \rightarrow O^{7+} + H_2^+$

Maxwellian - Maxwellian Rate Coefficients (cm^3/s)

O^{8+} Temp. (eV)	Equal Temp.	H_2 Temp. (eV) 1.	10.	100.	1000.	5000.	10000.	20000.
2.7E+03	3.03E-07	7.16E-08*	7.37E-08*	9.26E-08*	1.99E-07	3.98E-07	5.51E-07	7.66E-07
3.2E+03	3.28E-07	8.48E-08*	8.66E-08*	1.04E-07*	2.04E-07	4.00E-07	5.53E-07	7.67E-07
6.4E+03	4.61E-07	1.47E-07	1.48E-07	1.58E-07	2.33E-07	4.14E-07	5.63E-07	7.74E-07
1.1E+04	6.08E-07	2.04E-07	2.05E-07	2.11E-07	2.69E-07	4.35E-07	5.78E-07	7.84E-07
1.6E+04	7.23E-07	2.45E-07	2.46E-07	2.51E-07	3.00E-07	4.54E-07	5.93E-07	7.94E-07
2.0E+04	8.02E-07	2.74E-07	2.75E-07	2.80E-07	3.24E-07	4.70E-07	6.05E-07	8.02E-07

Accuracy: * - Possible Error Greater Than 10%
** - Possible Error Greater Than 100%

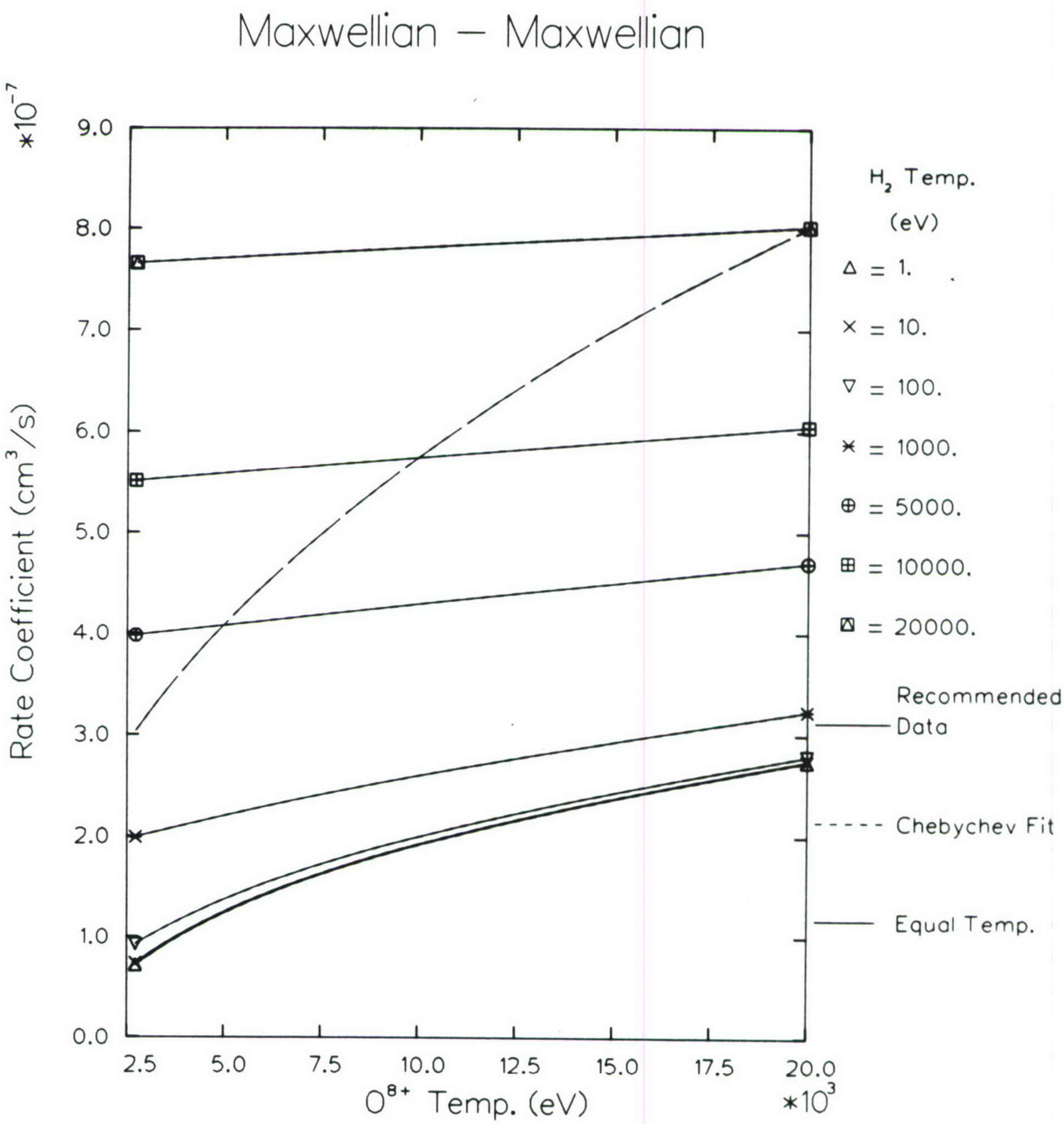
Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 2.7E+03 eV, E_{max} = 2.0E+04 eV

Chebychev Fitting Parameters for Rate Coefficients

H_2 Temp. (eV)	C1	C2	C3	C4	C5	C6	C7
1.	3.331E-07	1.006E-07	6.205E-09	7.415E-10	2.182E-10	-6.949E-12	
10.	3.353E-07	9.984E-08	6.368E-09	7.306E-10	2.098E-10	-3.008E-12	
100.	3.565E-07	9.284E-08	7.664E-09	6.990E-10	1.648E-10	-1.808E-13	
1000.	5.016E-07	6.128E-08	1.043E-08	9.571E-10	5.689E-11	5.119E-12	
5000.	8.521E-07	3.507E-08	7.725E-09	1.064E-09	9.261E-11	4.034E-12	
10000.	1.144E-06	2.622E-08	5.982E-09	8.819E-10	8.790E-11	5.087E-12	
20000.	1.560E-06	1.753E-08	4.031E-09	6.019E-10	6.093E-11	3.393E-12	
Equal Temp.	1.048E-06	2.485E-07	2.926E-08	1.326E-09	-5.962E-10	-2.283E-10	

See appendix for Chebychev fit details.

$O^{8+} + H_2 \rightarrow O^{7+} + H_2^+$



Total Electron Capture Rate Coefficients for
$H_2 + O^{8+} \rightarrow O^{7+} + H_2^+$

Beam - Maxwellian Rate Coefficients (cm^3/s)

O^{8+} Temp. (eV)	H_2 Energy (eV/amu) 10000.	20000.	40000.	50000.	70000.	80000.	100000.
2.7E+03	6.82E-07	9.65E-07	1.34E-06	1.42E-06	1.45E-06	1.37E-06	1.13E-06
3.2E+03	6.83E-07	9.64E-07	1.34E-06	1.42E-06	1.45E-06	1.37E-06	1.13E-06
6.4E+03	6.90E-07	9.70E-07	1.33E-06	1.41E-06	1.44E-06	1.36E-06	1.12E-06
1.1E+04	7.00E-07	9.77E-07	1.33E-06	1.41E-06	1.42E-06	1.35E-06	1.11E-06
1.6E+04	7.11E-07	9.80E-07	1.32E-06	1.41E-06	1.41E-06	1.34E-06	1.10E-06
2.0E+04	7.18E-07	9.88E-07	1.32E-06	1.40E-06	1.40E-06	1.33E-06	1.09E-06

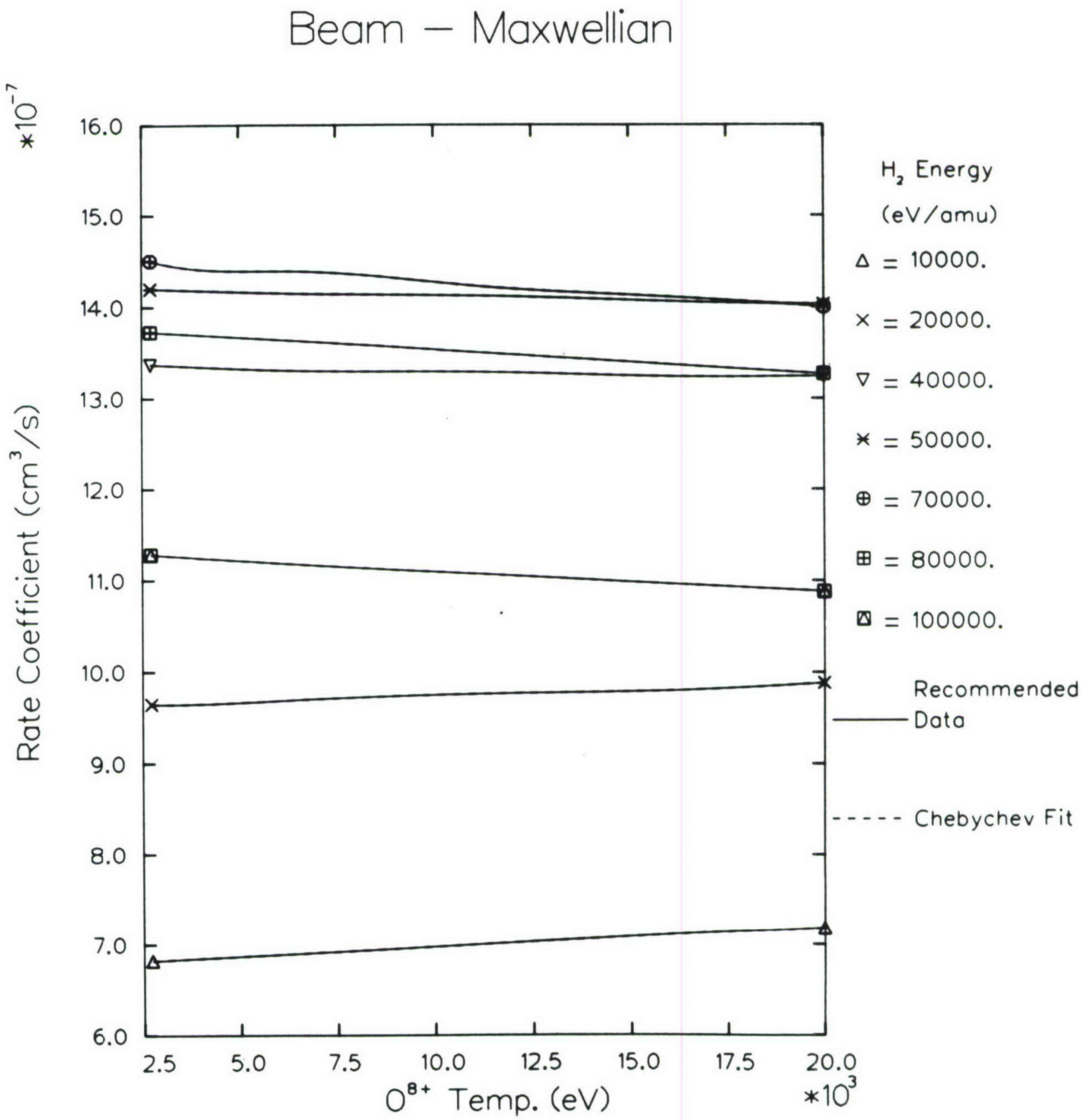
Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 2.7E+03 eV, E_{max} = 2.0E+04 eV

Chebychev Fitting Parameters for Rate Coefficients

H_2 Energy (eV/amu)	C1	C2	C3	C4	C5	C6	C7
10000.	1.392E-06	1.760E-08	4.210E-09	4.894E-10	-2.159E-10	-3.085E-10	
20000.	1.946E-06	1.124E-08	2.259E-09	-1.566E-10	1.396E-09	7.294E-10	
40000.	2.660E-06	-6.484E-09	1.359E-11	-8.869E-10	5.578E-10	1.216E-09	
50000.	2.825E-06	-8.131E-09	-1.679E-09	-1.204E-09	1.601E-10	8.295E-10	
70000.	2.859E-06	-2.347E-08	-5.117E-09	-3.988E-10	8.584E-10	-1.200E-09	
80000.	2.710E-06	-2.221E-08	-5.556E-09	-7.981E-10	2.461E-10	2.121E-10	
100000.	2.224E-06	-1.905E-08	-3.997E-09	-8.502E-10	-2.683E-11	-1.165E-10	

See appendix for Chebychev fit details.

$$H_2 + O^{8+} \rightarrow O^{7+} + H_2^+$$



2. Ionization of H, He, and H_2 in Collisions with C^{q+} and O^{q+} Ions

2.1 General Remarks 2-1

2.1.1 Theoretical and semiempirical formulae . . 2-1
2.1.2 Experimental methods 2-4
2.1.3 Dissociative, non-dissociative, double and transfer ionization 2-6

2.2 Ionization of H by C^{q+} 2-8

C^{+} + H 2-8
C^{2+} + H 2-12
C^{3+} + H 2-16
C^{4+} + H 2-20
C^{5+} + H 2-24
C^{6+} + H 2-28

2.3 Ionization of H by O^{q+} 2-32

O^{+} + H 2-32
O^{2+} + H 2-36
O^{3+} + H 2-40
O^{4+} + H 2-44
O^{5+} + H 2-48
O^{6+} + H 2-52
O^{7+} + H 2-56
O^{8+} + H 2-60

2.4 Ionization of He by C^{q+} 2-64

C^{+} + He 2-64
C^{2+} + He 2-68
C^{3+} + He 2-72
C^{4+} + He 2-76
C^{5+} + He 2-80
C^{6+} + He 2-84

2.5 Ionization of He by O^{q+} 2-88

O^{+} + He 2-88
O^{2+} + He 2-92
O^{3+} + He 2-96
O^{4+} + He 2-100
O^{5+} + He 2-104
O^{6+} + He 2-108
O^{7+} + He 2-112
O^{8+} + He 2-116

2.6 Ionization of H_2 by C^{q+} 2-120

$C^{+} + H_2$ 2-120
$C^{2+} + H_2$ 2-124
$C^{3+} + H_2$ 2-128
$C^{4+} + H_2$ 2-132
$C^{5+} + H_2$ 2-136
$C^{6+} + H_2$ 2-140

2.7 Ionization of H_2 by O^{q+} 2-144

$O^{+} + H_2$ 2-144
$O^{2+} + H_2$ 2-148
$O^{3+} + H_2$ 2-152
$O^{4+} + H_2$ 2-156
$O^{5+} + H_2$ 2-160
$O^{6+} + H_2$ 2-164
$O^{7+} + H_2$ 2-168
$O^{8+} + H_2$ 2-172

2. IONIZATION OF H, He, AND H_2 IN COLLISIONS WITH C^{q+} AND O^{q+} IONS

2.1 General Remarks

This chapter contains recommended cross section and reaction rate coefficients for the single ionization process

$$A^{q+} + B \rightarrow A^{q+} + B^{+} + e, \; 1 \leq q \leq Z \qquad (2.1)$$

where A = C, O and B = H, He, and H_2. Both theoretical and experimental investigations of reactions (2.1) are relatively straightforward in the high-energy region ($E \gtrsim 50$ q keV/amu), where ionization is the dominant inelastic process in $A^{q+} + B$ collisions. However, the investigations of reactions (2.1) encounter significant difficulties in the region below the cross section maximum [E_m (keV/amu) ~(50-100)q], where the charge exchange channel dominates.

2.1.1 Theoretical and semiempirical formulae

In the adiabatic energy region [E (keV/amu) << 25 q] the ionization cross section is predicted to be exponentially small [G.1]

$$\sigma_{ion} \simeq a_1 \frac{q}{E} \exp\left(-a_2 \frac{E_{ion} q}{E}\right), \qquad (2.2)$$

where a_1 and a_2 are constants and E_{ion} is the ionization potential of the target. In the high energy region the cross section can be well-represented by the Bethe approximation

$$\sigma_{Bethe} = 3.52 \times 10^{-16} \frac{q^2}{v^2} \left\{ M^2_{ion} \left[\ln\left(\frac{v^2}{c^2-v^2}\right) - \frac{v^2}{c^2} \right] + C_{ion} + \frac{\gamma_{ion}}{v^2} \right\} (cm^2) \qquad (2.3)$$

$$v^2 = 4 \times 10^{-5}\ E(eV/amu) \qquad (2.4)$$

where c = 137 (the speed of light in atomic units) and the parameters M^2_{ion}, C_{ion}, and γ_{ion} for the H, He, and H_2 targets are given in Table 2.1 (see e.g., [G.17], [G.18]). An accurate theoretical description of the ionization process in the intermediate region where the cross section is maximum still does not exist. However, methods based on the coupled channel formalism in which the continuum is represented by suitably chosen pseudo-states seem to be the most adequate for this region [G.19]. Beyond the energy of the cross-section maximum but below the region of applicability of Bethe-Born approximation (2.3), the continuum distorted wave method seems to provide an accurate description [G.20]. In the absence of elaborate theoretical models for the ionization process in the low and intermediate energy regions, a semiempirical scaling formula has been proposed [G.17], [G.18] for the A^{q+} + H, He, H_2 collision systems. The semiempirical formula is a combination of Eqs. (2.2) and (2.3) and has the form

$$\sigma_{ion} = \exp\left(-\lambda\, q/v^2\right) \sigma_{Bethe} \qquad (2.5)$$

where λ is a fitting parameter. The values of λ for H, He, and H_2 targets, obtained by fitting Eq. (2.5) to the available experimental ionization cross section data with $q > (Z/2)$ are given in Table 2.1 ([G.17], [G.18]).

Table 2.1. Parameters for Equation 2.3

Target	M^2_{ion}	C_{ion}	γ_{ion}	λ	Ref.
H	0.283	4.04	-0.662	0.76	[G.17]
He	0.489	5.52	-1.21	2.0	[G.18]
H_2	0.721	9.06	-1.3	1.0	[G.18]

The values of λ given in Table 2.1 reproduce the experimental data within a 30% accuracy for $E \gtrsim 30$ keV/amu for H-target, and $E \gtrsim 80$ keV/amu for He and H_2 targets.

The relationship (2.5) can also be used to determine λ for each specific ionic charge state q, which then gives a more accurate value for this parameter. For instance, by using the He-target experimental data from Refs. [G.21], [G.22] and those quoted in Ref. [G.18], we obtained the values $\lambda_{He} = 1$ (q=1), 2.4 (q=2), 1.6 (q=3), 2 (q=4), 2.2 (q=5), 2.4 (q=6), 2.5 (q=7,8).

The analysis of existing experimental data in the intermediate energy region for C^{q+}, O^{q+} + H [G.23], C^{q+}, O^{q+} + H_2 [G.24], and for H^+, He^{2+}, Li^{3+} + He [G.21], allows one to formulate the following empirical scalings for the energy E_m

at which the cross section maximum appears, and for the value of the cross-section maximum $\sigma_{ion}^{max} = \sigma_{ion}(E_m)$,

$$E_m = a\ q^{0.65} \times 10^4\ \mathrm{eV/amu} \qquad (2.6)$$

$$\sigma_{ion}^{max} = b\ q^{\beta} \times 10^{-16}\ \mathrm{cm}^2 \qquad (2.7)$$

where the values of parameters a, b, and β are given in Table 2.2.

Table 2.2. Parameters for Equations 2.6 and 2.7

Collision Pair	a	b	β
$C^{q+} + H$	4.3	1.66	1.3
$O^{q+} + H$	4.14	1.75	1.3
$C^{q+}, O^{q+} + He$	10	0.843	1.3
$C^{q+} + H_2$	6.1	2.39	1.25
$O^{q+} + H_2$	4.65	2.39 $(q < 4)$ 2.0 $(q = 5)$ 2.2 $(q > 6)$	1.25

The value b = 2.2 for $O^{q+} + H_2$ $(q > 6)$ has been taken as the average of the values for the ions with $q < 5$.

2.1.2 Experimental methods

For the reactions considered, many of the target ionization cross-sections have been measured using the condenser-plate method. This technique has been discussed in detail in

the literature [G.22, G.25]. A fast charge-to-mass selected ion beam is directed into a differentially-pumped gas cell. In this cell are placed positively and negatively biased conducting plates which collect slow electrons and ions produced from a well-defined interaction length in the target cell. Cross sections are deduced from the measured ion and/or electron currents, and from measurements of pressure in the cell. Under single-collision conditions, both ion and electron current yields vary linearly with gas pressure, and the cross section is determined by the slope.

Other processes which must be taken into account include secondary electron emission from the plates and also resonant charge exchange collisions of the slow ions with the target gas before they reach the plates. For the He and H_2 ionization measurements, the relative contributions of single and double ionization must also be measured or estimated in some way. This has usually been accomplished by the application of single-particle detectors and time-of-flight techniques to identify the slow ions. At the lower collision energies, electron capture must also be considered as a source of slow ions. This has been accomplished by detecting the ions in coincidence with ejected electrons [G.21].

Measurements of ionization of atomic hydrogen [G.23] have utilized a thermal beam emanating from a thermal-dissociation atomic hydrogen target (see Sect. 1.1.5). This thermal beam

was crossed by a fast ion beam. The slow product protons and ejected electrons were detected in coincidence to distinguish protons formed in electron-capture and ionization events. The H-atom target thickness was determined by using a probe beam of H^+ and normalizing to the well-established H^+ + H cross section. This same method has also been applied to measurements of ionization of H_2 [G.24]. The ion products resulting from dissociative and non-dissociative collisions could in this case be distinguished by the combination of time-of-flight and electron-ion coincidence techniques.

2.1.3 Dissociative, non-dissociative, double and transfer ionization

As noted above, the time-of-flight coincidence experiments on H_2 [G.24] distinguish the products of dissociative and non-dissociative collisions. The non-dissociative collisions produce H_2^+ ions, while there are three possibilities for the dissociative channels. Direct dissociative ionization yields the products H^+ + H + e. Double ionization yields the products H^+ + H^+ + 2e. Transfer ionization (double electron capture followed by autoionization) yields the products H^+ + H^+ + e. This last process is expected to be important only at the lower collision energies. The available data for sum of the dissociative channels indicate that these processes are relatively important only at the lower collision energies, and have cross sections that are about an order of magnitude below

that for the non-dissociative collisions at higher energies. Their potential contributions have been taken into account in estimating uncertainties in those cases where specific data on these channels were not available.

Both double ionization and transfer ionization are also possible for He targets. The former is expected to be most important at the higher collision energies (well above the single ionization cross-section maximum), and the latter at the lower energies. The effects of these processes on the available experimental data for ionization of He are relatively small [G.22, G.26], and have been taken into account in the estimations of uncertainties in the recommended single-ionization cross sections.

In charge-exchange experiments, transfer ionization is also registered as part of the total single-electron-capture cross section in ion-beam - gas-target experiments where the cross section is deduced from charge analysis of the fast ion products. Again, this is expected to be a relatively small contribution for the collision systems considered here, and has been considered in estimating uncertainties in the recommended cross sections.

Ionization Cross Sections for
$C^{+} + H \rightarrow C^{+} + H^{+} + e^{-}$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
7.0E+03	1.16E+08	5.06E-17
1.0E+04	1.39E+08	6.95E-17
2.0E+04	1.96E+08	1.15E-16
4.0E+04	2.78E+08	1.44E-16
7.0E+04	3.68E+08	1.36E-16
1.0E+05	4.39E+08	1.18E-16
2.0E+05	6.21E+08	7.70E-17
4.0E+05	8.78E+08	4.57E-17
7.0E+05	1.16E+09	2.91E-17
1.0E+06	1.39E+09	2.16E-17
2.0E+06	1.96E+09	1.18E-17
4.0E+06	2.77E+09	6.12E-18
7.0E+06	3.65E+09	3.63E-18
1.0E+07	4.36E+09	2.60E-18

References: T.9, T.51, T.53

Accuracy: 50% for E < $1x10^5$ eV/amu; 40% for E $\geq$ $1x10^5$ eV/amu

Note: No experimental data are available for this reaction. The recommended cross section was constructed on the basis of data provided by the formulae given in Refs. [T.51] and [T.53], which agree in the region $3x10^4 \leq E(eV/amu) \leq 2x10^5$, as well as by using the empirical scaling for the maximum cross section derived from the experimental data on C^{q+} + H ionization (q = 2-4). See general remarks in section 2.1 for details.

For Chebychev fits of the above cross sections it is necessary to use the following parameters.
E_{min} = 7.0E+03 eV/amu, E_{max} = 1.0E+07 eV/amu

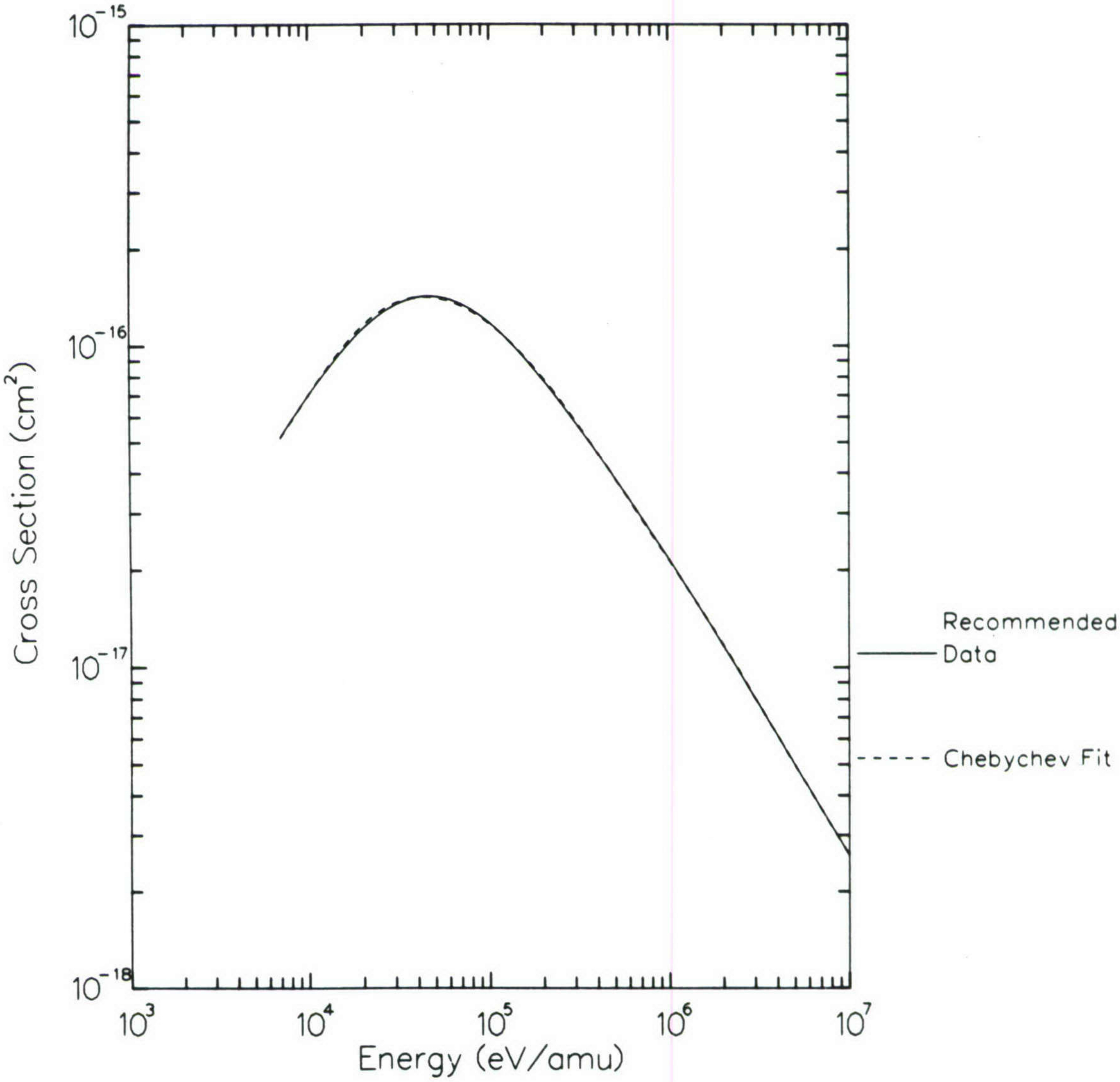
Chebychev Fitting Parameters for Cross Sections

C1	C2	C3	C4	C5	C6	C7	C8	C9
1.098E-16	-5.064E-17	-2.503E-17	3.449E-17	-8.837E-18	-6.769E-18	6.053E-18	-1.179E-18	-4.127E-19

The fit represents the above cross sections with an rms deviation of 1.7%.
The maximum deviation is 3.3% at 2.0E+04 eV/amu.
See appendix for Chebychev fit details.

$C^+ + H \rightarrow C^+ + H^+ + e^-$

Cross Section vs. Energy



Ionization Rate Coefficients for
$H + C^{+} \rightarrow C^{+} + H^{+} + e^{-}$

Beam - Maxwellian Rate Coefficients (cm^3/s)

C^{+} Temp. (eV)	H Energy (eV/amu) 10000.	20000.	40000.	70000.	100000.	200000.	500000.
1.0E+00	9.65E-09	2.26E-08	4.00E-08	5.00E-08	5.18E-08	4.78E-08	3.76E-08
2.0E+00	9.65E-09	2.26E-08	4.00E-08	5.00E-08	5.18E-08	4.78E-08	3.76E-08
4.0E+00	9.66E-09	2.26E-08	4.00E-08	5.00E-08	5.18E-08	4.78E-08	3.76E-08
7.0E+00	9.66E-09	2.26E-08	4.00E-08	5.00E-08	5.18E-08	4.78E-08	3.76E-08
1.0E+01	9.66E-09	2.26E-08	4.00E-08	5.00E-08	5.18E-08	4.78E-08	3.76E-08
2.0E+01	9.66E-09	2.26E-08	4.00E-08	5.00E-08	5.18E-08	4.78E-08	3.76E-08
4.0E+01	9.66E-09	2.26E-08	4.00E-08	5.00E-08	5.18E-08	4.78E-08	3.76E-08
7.0E+01	9.67E-09	2.26E-08	4.00E-08	5.00E-08	5.18E-08	4.78E-08	3.76E-08
1.0E+02	9.67E-09	2.26E-08	4.00E-08	5.00E-08	5.18E-08	4.78E-08	3.76E-08
2.0E+02	9.69E-09	2.26E-08	4.00E-08	5.00E-08	5.18E-08	4.78E-08	3.76E-08
4.0E+02	9.72E-09	2.26E-08	4.00E-08	5.00E-08	5.18E-08	4.79E-08	3.76E-08
7.0E+02	9.77E-09	2.26E-08	4.00E-08	5.00E-08	5.18E-08	4.79E-08	3.76E-08
1.0E+03	9.80E-09	2.26E-08	3.99E-08	5.00E-08	5.18E-08	4.79E-08	3.76E-08
2.0E+03	9.84E-09	2.27E-08	4.00E-08	4.98E-08	5.18E-08	4.79E-08	3.76E-08
4.0E+03	9.95E-09	2.29E-08	3.99E-08	4.99E-08	5.18E-08	4.79E-08	3.76E-08
7.0E+03	1.03E-08	2.31E-08	3.99E-08	4.98E-08	5.18E-08	4.79E-08	3.76E-08
1.0E+04	1.07E-08	2.33E-08	3.99E-08	4.97E-08	5.17E-08	4.79E-08	3.75E-08
2.0E+04	1.22E-08	2.42E-08	3.99E-08	4.94E-08	5.15E-08	4.78E-08	3.76E-08

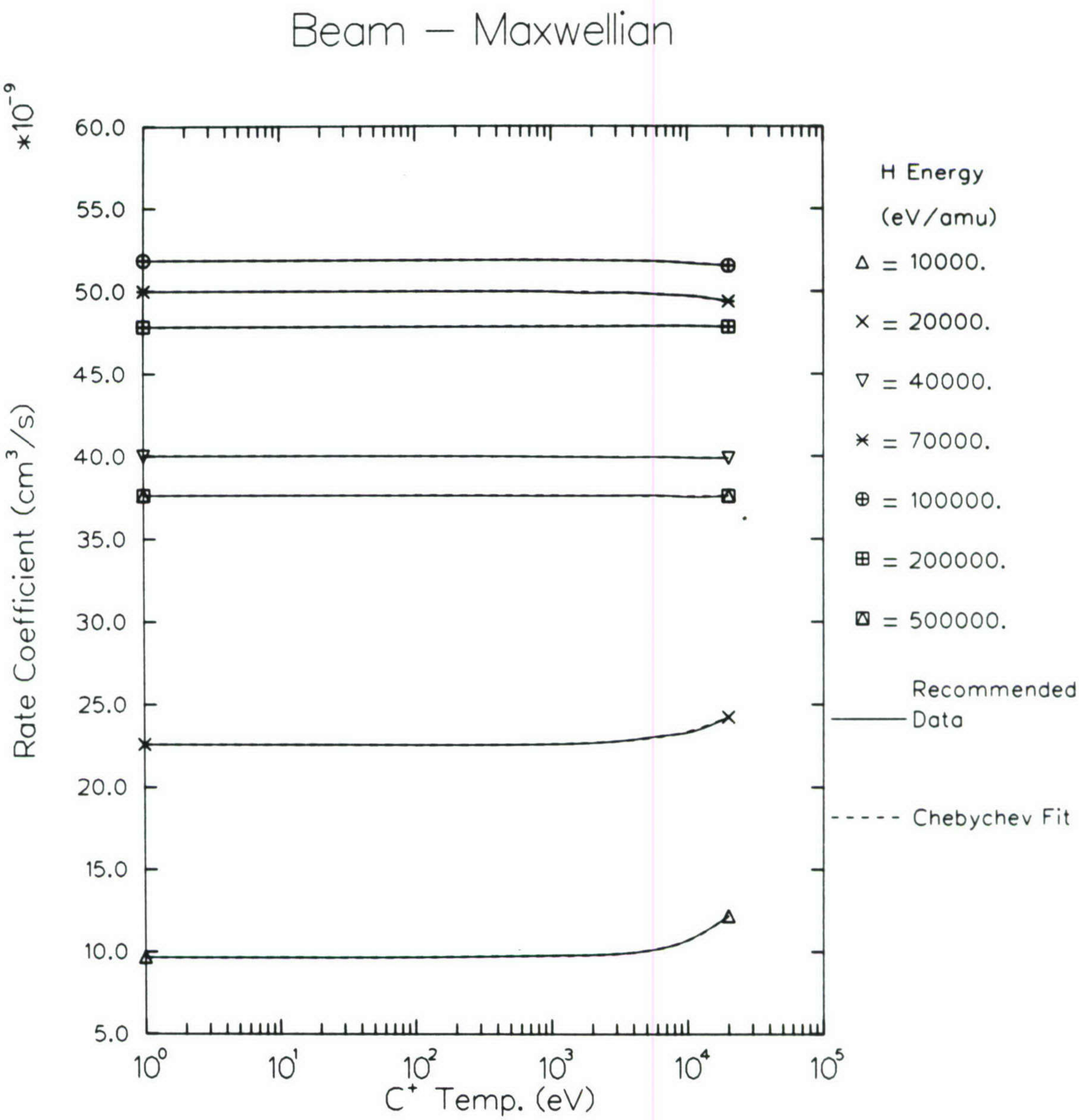
Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

Chebychev Fitting Parameters for Rate Coefficients

H Energy (eV/amu)	C1	C2	C3	C4	C5	C6	C7
10000.	2.015E-08	7.616E-10	5.623E-10	3.728E-10	2.288E-10	1.270E-10	5.657E-11
20000.	4.574E-08	5.236E-10	3.945E-10	2.422E-10	1.220E-10	5.307E-11	2.568E-11
40000.	7.993E-08	-6.174E-11	-2.451E-11	-3.027E-12	1.576E-12	-1.014E-12	-2.291E-12
70000.	9.974E-08	-2.028E-10	-1.396E-10	-7.941E-11	-3.860E-11	-2.048E-11	-1.832E-11
100000.	1.036E-07	-9.236E-11	-7.857E-11	-5.138E-11	-2.568E-11	-9.814E-12	-2.207E-12
200000.	9.569E-08	1.966E-11	-1.379E-12	-1.136E-11	-8.727E-12	-5.865E-12	-3.567E-12
500000.	7.518E-08	-1.840E-11	-1.365E-11	-3.988E-12	3.101E-12	6.664E-12	9.815E-12

See appendix for Chebychev fit details.

$H + C^+ \rightarrow C^+ + H^+ + e^-$



Ionization Cross Sections for
$C^{2+} + H \rightarrow C^{2+} + H^{+} + e^{-}$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
7.0E+03	1.16E+08	1.08E-16
1.0E+04	1.39E+08	1.48E-16
2.0E+04	1.96E+08	2.71E-16
4.0E+04	2.78E+08	4.04E-16
5.9E+04	3.37E+08	4.45E-16
7.0E+04	3.68E+08	4.44E-16
1.0E+05	4.39E+08	4.05E-16
2.0E+05	6.21E+08	2.99E-16
4.0E+05	8.78E+08	1.93E-16
7.0E+05	1.16E+09	1.24E-16
1.0E+06	1.39E+09	9.14E-17
2.0E+06	1.96E+09	4.95E-17
4.0E+06	2.77E+09	2.55E-17
7.0E+06	3.65E+09	1.51E-17
1.0E+07	4.36E+09	1.04E-17

References: E.65, E.66, T.9, T.51, T.52, T.53

Accuracy: 30% for E < 1.5×10^4 eV/amu; 15% for $1.5 \times 10^4 \leq$ E(eV/amu) $\leq 4 \times 10^5$; 20% for E > 4×10^5 eV/amu

Notes: (1) In the region $1.5 \times 10^4 \leq$ E(eV/amu) $\leq 4 \times 10^5$, the recommended cross section is determined by the available experimental data ([E.65], [E.66]). For E > 4×10^5 eV/amu, the cross section was constructed by using the semi-empirical scaling (see sect. 2.1.1), normalized to the experimental data in the energy region near the cross section maximum.

(2) In the region below 1.5×10^4 eV/amu, the cross section was constructed by extrapolation of experimental data according to the theoretical cross-section behavior [T.52], [T.53].

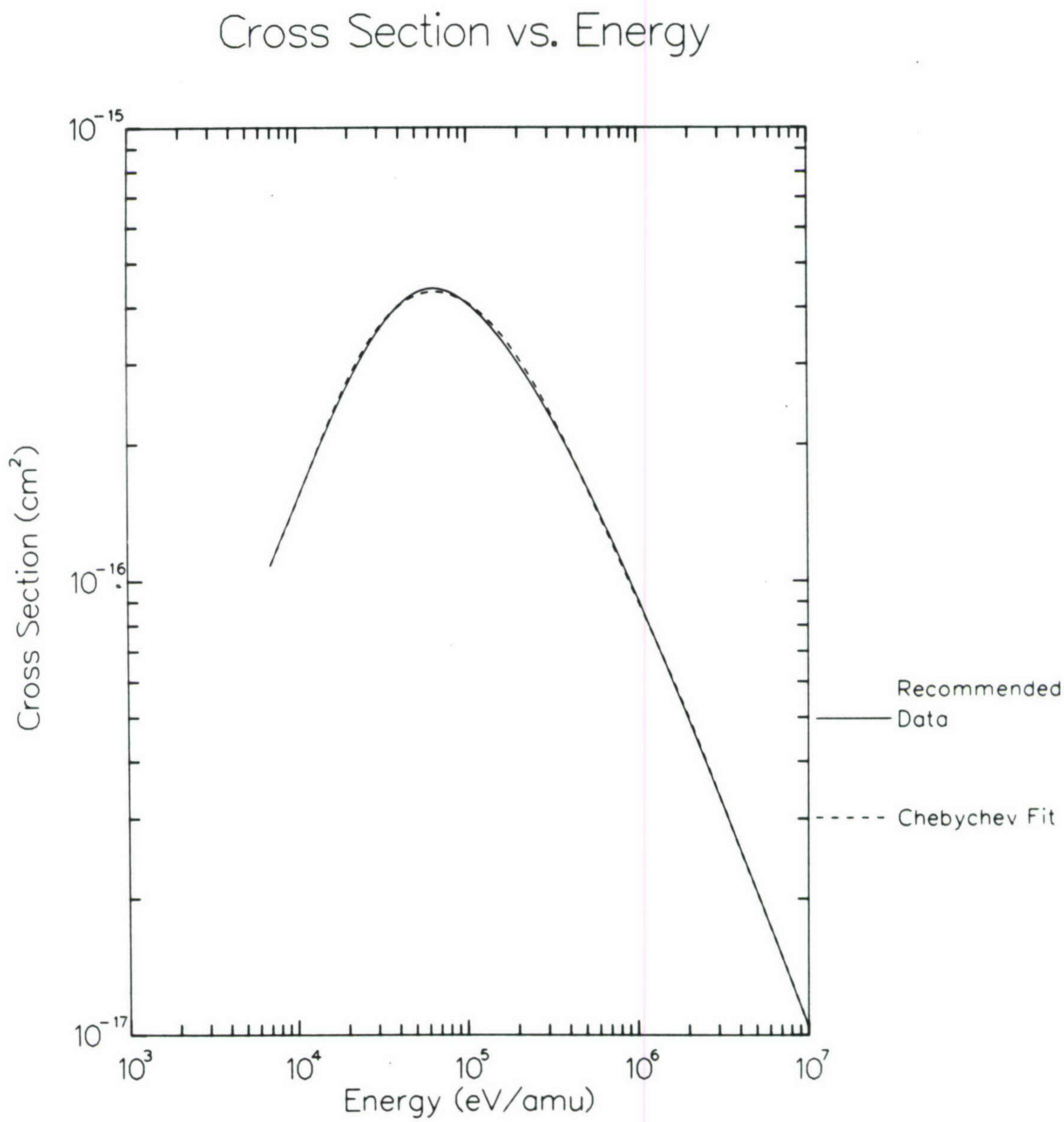
For Chebychev fits of the above cross sections it is necessary to use the following parameters.
E_{min} = 7.0E+03 eV/amu, E_{max} = 1.0E+07 eV/amu

Chebychev Fitting Parameters for Cross Sections

C1	C2	C3	C4	C5	C6	C7	C8	C9
3.250E-16	-1.179E-16	-1.156E-16	1.005E-16	2.624E-18	-3.614E-17	1.434E-17	4.553E-18	-4.560E-18

The fit represents the above cross sections with an rms deviation of 1.9%.
The maximum deviation is 3.9% at 2.0E+05 eV/amu.
See appendix for Chebychev fit details.

$C^{2+} + H \rightarrow C^{2+} + H^{+} + e^{-}$



Ionization Rate Coefficients for

$H + C^{2+} \rightarrow C^{2+} + H^{+} + e^{-}$

Beam - Maxwellian Rate Coefficients (cm^3/s)

C^{2+} Temp. (eV)	H Energy (eV/amu) 10000.	20000.	40000.	70000.	100000.	200000.	500000.
1.0E+00	2.06E-08	5.32E-08	1.12E-07	1.63E-07	1.78E-07	1.86E-07	1.60E-07
2.0E+00	2.06E-08	5.32E-08	1.12E-07	1.63E-07	1.78E-07	1.86E-07	1.60E-07
4.0E+00	2.06E-08	5.32E-08	1.12E-07	1.63E-07	1.78E-07	1.86E-07	1.60E-07
7.0E+00	2.06E-08	5.32E-08	1.12E-07	1.63E-07	1.78E-07	1.86E-07	1.60E-07
1.0E+01	2.06E-08	5.32E-08	1.12E-07	1.63E-07	1.78E-07	1.86E-07	1.60E-07
2.0E+01	2.06E-08	5.32E-08	1.12E-07	1.63E-07	1.78E-07	1.86E-07	1.60E-07
4.0E+01	2.06E-08	5.32E-08	1.12E-07	1.63E-07	1.78E-07	1.86E-07	1.60E-07
7.0E+01	2.06E-08	5.32E-08	1.12E-07	1.63E-07	1.78E-07	1.86E-07	1.60E-07
1.0E+02	2.06E-08	5.32E-08	1.12E-07	1.63E-07	1.78E-07	1.86E-07	1.60E-07
2.0E+02	2.06E-08	5.32E-08	1.12E-07	1.63E-07	1.78E-07	1.86E-07	1.60E-07
4.0E+02	2.07E-08	5.32E-08	1.12E-07	1.63E-07	1.78E-07	1.86E-07	1.60E-07
7.0E+02	2.09E-08	5.33E-08	1.12E-07	1.63E-07	1.78E-07	1.86E-07	1.60E-07
1.0E+03	2.09E-08	5.34E-08	1.12E-07	1.63E-07	1.78E-07	1.86E-07	1.60E-07
2.0E+03	2.11E-08	5.38E-08	1.12E-07	1.63E-07	1.78E-07	1.86E-07	1.60E-07
4.0E+03	2.15E-08	5.45E-08	1.12E-07	1.63E-07	1.78E-07	1.86E-07	1.60E-07
7.0E+03	2.25E-08	5.56E-08	1.13E-07	1.62E-07	1.78E-07	1.86E-07	1.60E-07
1.0E+04	2.36E-08	5.66E-08	1.13E-07	1.62E-07	1.78E-07	1.86E-07	1.60E-07
2.0E+04	2.78E-08	6.01E-08	1.14E-07	1.61E-07	1.78E-07	1.85E-07	1.60E-07

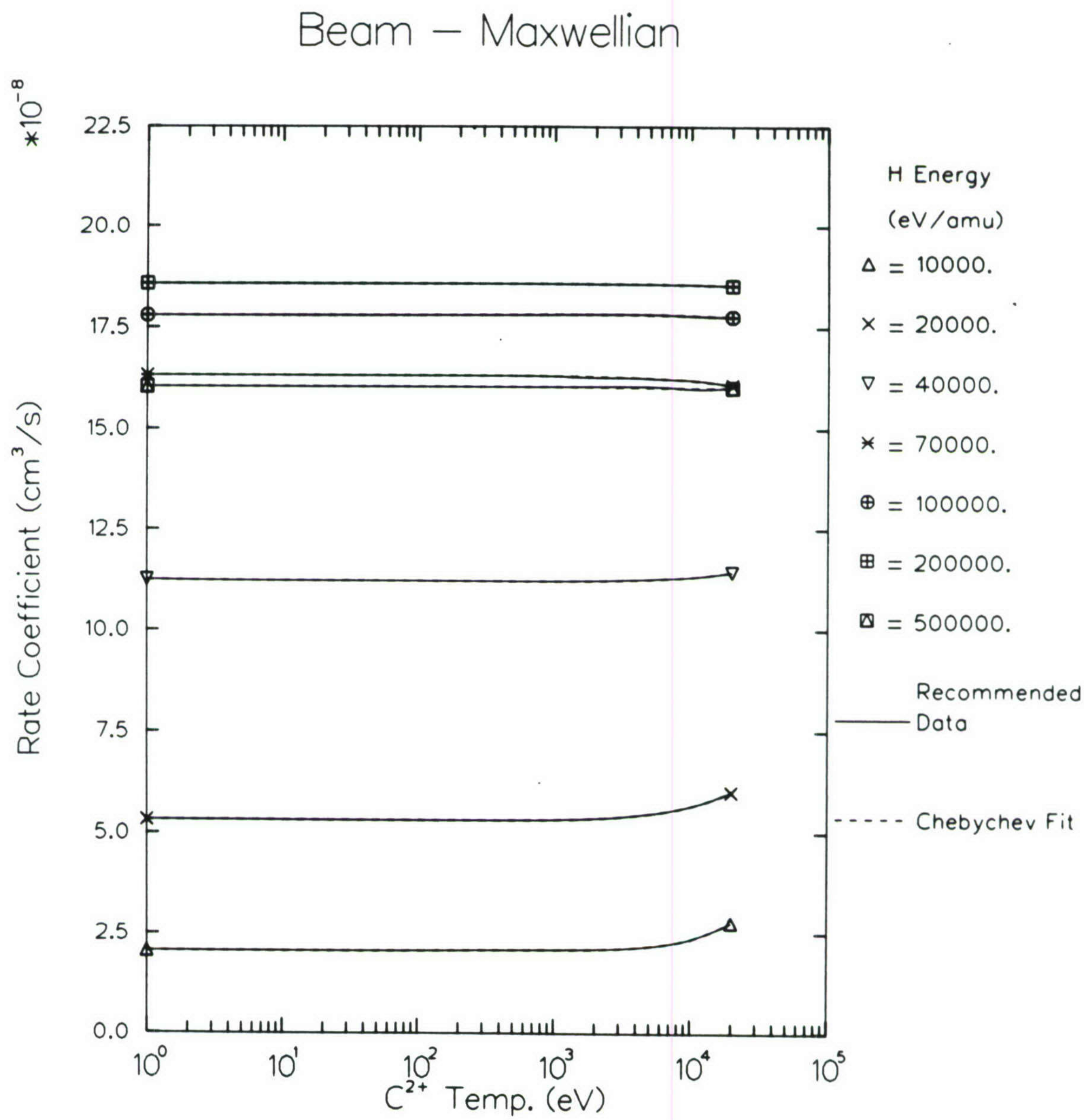
Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

Chebychev Fitting Parameters for Rate Coefficients

H Energy (eV/amu)	C1	C2	C3	C4	C5	C6	C7
10000.	4.354E-08	2.194E-09	1.617E-09	1.055E-09	6.269E-10	3.350E-10	1.475E-10
20000.	1.089E-07	2.234E-09	1.672E-09	1.002E-09	4.797E-10	1.825E-10	5.365E-11
40000.	2.252E-07	6.682E-10	5.364E-10	3.406E-10	1.713E-10	6.861E-11	2.051E-11
70000.	3.255E-07	-7.919E-10	-5.352E-10	-2.954E-10	-1.369E-10	-6.709E-11	-5.707E-11
100000.	3.559E-07	2.454E-12	-1.120E-10	-1.197E-10	-7.209E-11	-2.952E-11	-6.137E-12
200000.	3.713E-07	-1.134E-10	-1.003E-10	-7.297E-11	-4.291E-11	-2.246E-11	-1.512E-11
500000.	3.206E-07	-1.088E-10	-7.989E-11	-2.982E-11	6.941E-12	2.586E-11	4.100E-11

See appendix for Chebychev fit details.

$H + C^{2+} \rightarrow C^{2+} + H^{+} + e^{-}$



Ionization Cross Sections for
$C^{3+} + H \rightarrow C^{3+} + H^{+} + e^{-}$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
2.0E+04	1.96E+08	1.20E-16
4.0E+04	2.78E+08	3.82E-16
7.0E+04	3.68E+08	6.59E-16
1.0E+05	4.39E+08	6.76E-16
2.0E+05	6.21E+08	5.33E-16
4.0E+05	8.78E+08	3.59E-16
7.0E+05	1.16E+09	2.44E-16
1.0E+06	1.39E+09	1.84E-16
2.0E+06	1.96E+09	1.00E-16
4.0E+06	2.77E+09	5.41E-17
7.0E+06	3.65E+09	3.29E-17
1.0E+07	4.36E+09	2.32E-17

References: E.65, E.66, T.8, T.9. T.51, T.52

Accuracy: 15% for $E \leq 4x10^5$ eV/amu, 20% for $E > 4x10^5$ eV/amu

Note: The cross section below $E = 4x10^5$ eV/amu represents the experimental data, [E.65], [E.66], which, in the region around the cross section maximum, coincide with both the semi-empirical scaling (see sect. 2.1.1) and calculations of Ref. [T.52]. For $E > 4x10^5$ eV/amu, the extrapolation is made by using the semi-empirical scaling (see sect. 2.1.1).

For Chebychev fits of the above cross sections it is necessary to use the following parameters.
E_{min} = 2.0E+04 eV/amu, E_{max} = 1.0E+07 eV/amu

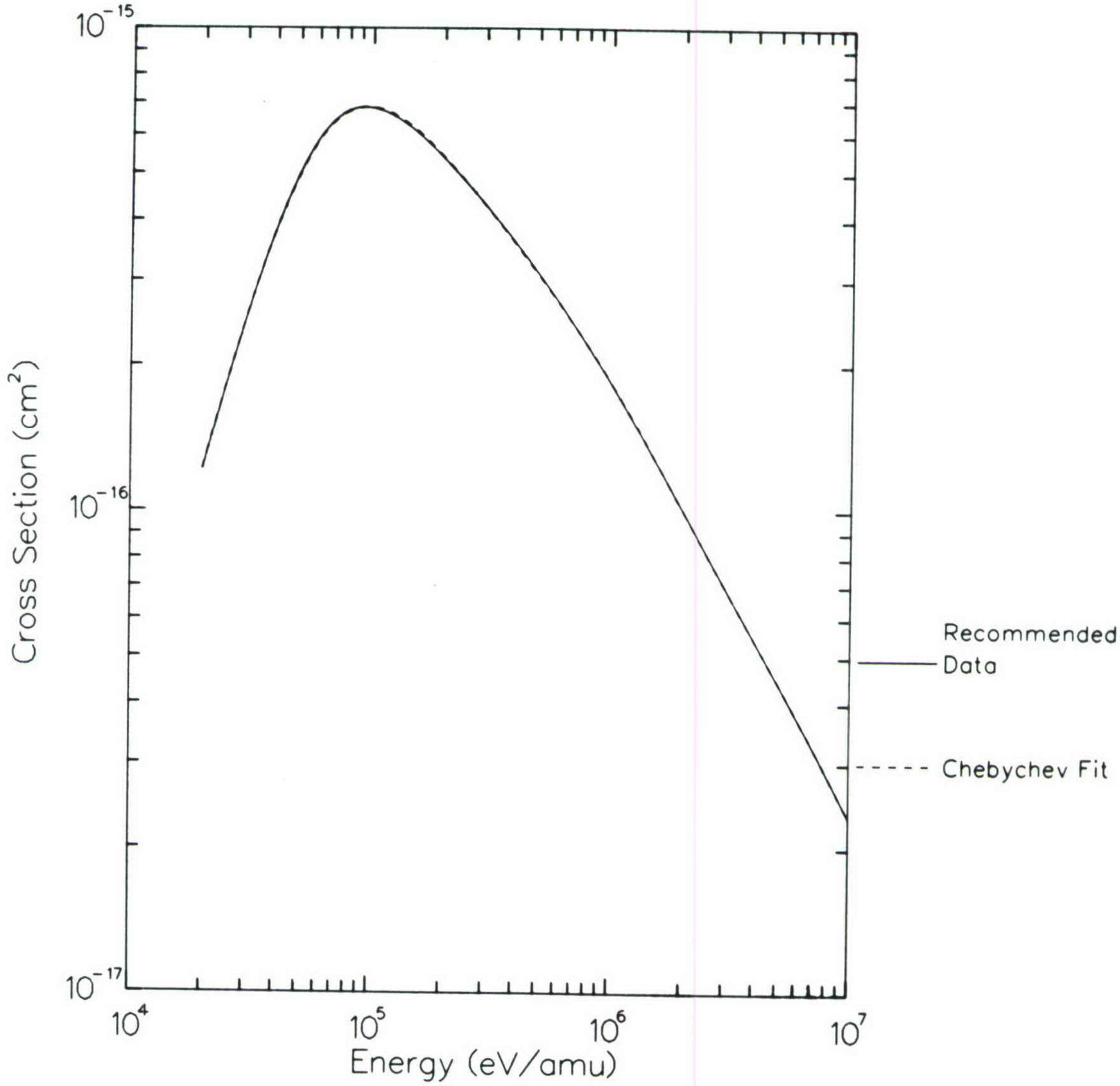
Chebychev Fitting Parameters for Cross Sections

C1	C2	C3	C4	C5	C6	C7	C8	C9
4.671E-16	-1.581E-16	-1.785E-16	1.796E-16	-4.290E-17	-3.900E-17	4.895E-17	-3.091E-17	1.050E-17

The fit represents the above cross sections with an rms deviation of 0.5%.
The maximum deviation is 0.9% at 1.0E+06 eV/amu.
See appendix for Chebychev fit details.

$C^{3+} + H \rightarrow C^{3+} + H^{+} + e^{-}$

Cross Section vs. Energy



Total Ionization Rate Coefficients for
$H + C^{3+} \rightarrow C^{3+} + H^{+} + e^{-}$

Beam - Maxwellian Rate Coefficients (cm^3/s)

C^{3+} Temp. (eV)	H Energy (eV/amu) 20000.	40000.	70000.	100000.	200000.	400000.	500000.
1.0E+00	1.19E-08**	1.06E-07	2.42E-07	2.97E-07	3.31E-07	3.15E-07	3.04E-07
2.0E+00	1.19E-08**	1.06E-07	2.42E-07	2.97E-07	3.31E-07	3.15E-07	3.04E-07
4.0E+00	1.20E-08*	1.06E-07	2.42E-07	2.97E-07	3.31E-07	3.15E-07	3.04E-07
7.0E+00	1.20E-08*	1.06E-07	2.42E-07	2.97E-07	3.31E-07	3.15E-07	3.04E-07
1.0E+01	1.21E-08*	1.06E-07	2.42E-07	2.97E-07	3.31E-07	3.15E-07	3.04E-07
2.0E+01	1.22E-08*	1.06E-07	2.42E-07	2.97E-07	3.31E-07	3.15E-07	3.04E-07
4.0E+01	1.23E-08*	1.06E-07	2.42E-07	2.97E-07	3.31E-07	3.15E-07	3.04E-07
7.0E+01	1.25E-08*	1.06E-07	2.42E-07	2.97E-07	3.31E-07	3.15E-07	3.04E-07
1.0E+02	1.27E-08*	1.06E-07	2.42E-07	2.97E-07	3.31E-07	3.15E-07	3.04E-07
2.0E+02	1.30E-08*	1.06E-07	2.42E-07	2.97E-07	3.31E-07	3.15E-07	3.04E-07
4.0E+02	1.36E-08*	1.06E-07	2.41E-07	2.97E-07	3.31E-07	3.15E-07	3.04E-07
7.0E+02	1.42E-08*	1.07E-07	2.41E-07	2.98E-07	3.32E-07	3.15E-07	3.04E-07
1.0E+03	1.48E-08*	1.07E-07	2.41E-07	2.98E-07	3.32E-07	3.15E-07	3.04E-07
2.0E+03	1.62E-08*	1.07E-07	2.41E-07	2.98E-07	3.32E-07	3.15E-07	3.04E-07
4.0E+03	1.85E-08*	1.09E-07	2.40E-07	2.98E-07	3.32E-07	3.15E-07	3.04E-07
7.0E+03	2.13E-08*	1.11E-07	2.39E-07	2.98E-07	3.32E-07	3.15E-07	3.04E-07
1.0E+04	2.39E-08*	1.12E-07	2.39E-07	2.97E-07	3.32E-07	3.15E-07	3.04E-07
2.0E+04	3.13E-08*	1.18E-07	2.36E-07	2.96E-07	3.32E-07	3.15E-07	3.04E-07

Accuracy: * - Possible Error Greater Than 10%
** - Possible Error Greater Than 100%

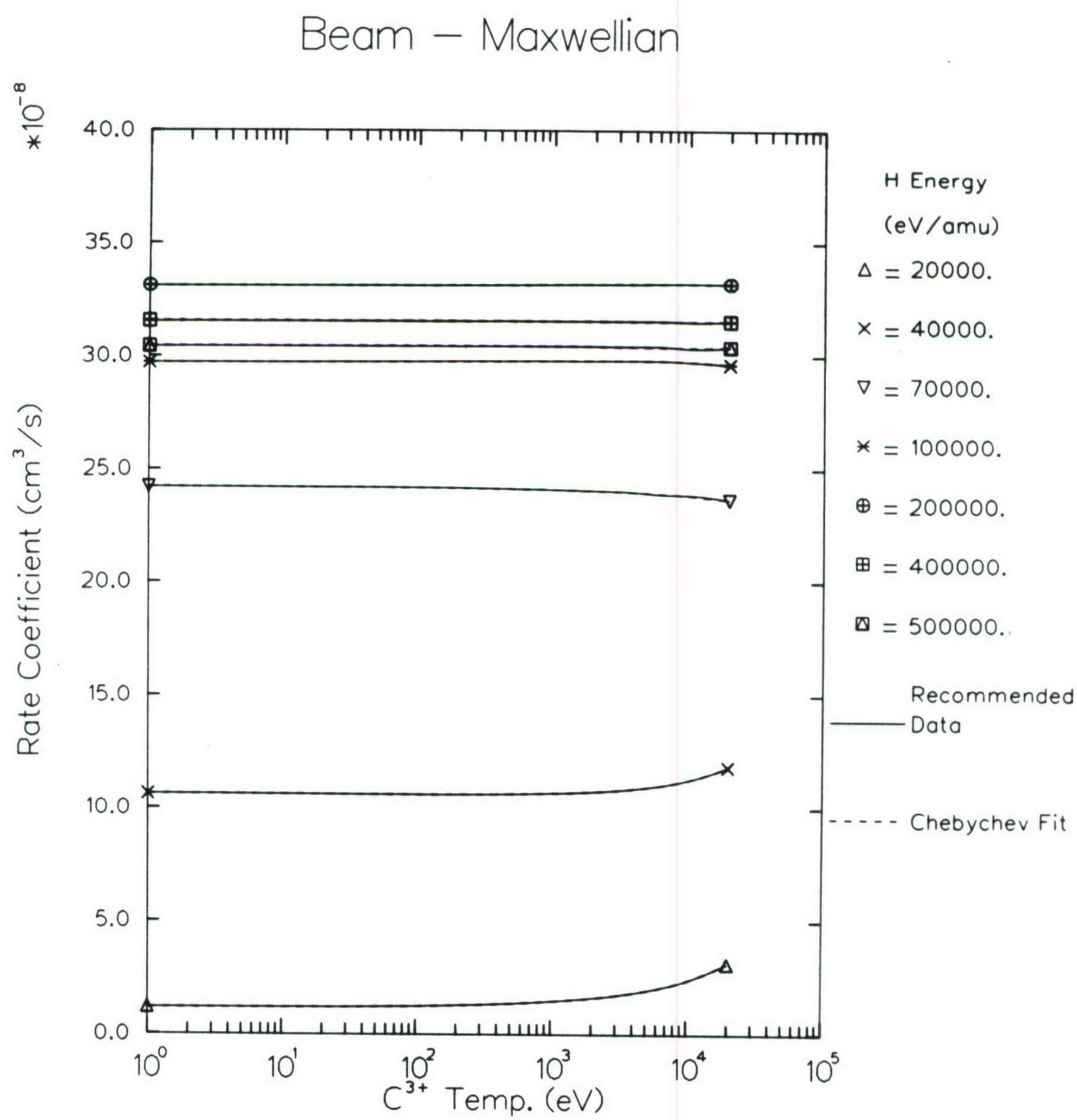
Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

Chebychev Fitting Parameters for Rate Coefficients

H Energy (eV/amu)	C1	C2	C3	C4	C5	C6	C7
20000.	3.276E-08	7.393E-09	4.288E-09	2.014E-09	8.215E-10	2.968E-10	9.085E-11
40000.	2.169E-07	4.103E-09	2.902E-09	1.666E-09	7.809E-10	2.956E-10	8.738E-11
70000.	4.815E-07	-2.264E-09	-1.196E-09	-4.906E-10	-1.712E-10	-5.284E-11	-2.059E-11
100000.	5.943E-07	1.179E-10	-3.011E-10	-3.661E-10	-2.325E-10	-1.012E-10	-2.865E-11
200000.	6.630E-07	5.482E-10	1.514E-10	-4.446E-11	-7.177E-11	-4.761E-11	-3.192E-11
400000.	6.307E-07	4.017E-11	-2.105E-11	-2.256E-11	-8.654E-13	1.769E-11	3.429E-11
500000.	6.085E-07	-1.855E-10	-1.366E-10	-4.707E-11	1.867E-11	5.218E-11	8.004E-11

See appendix for Chebychev fit details.

$H + C^{3+} \rightarrow C^{3+} + H^{+} + e^{-}$



Ionization Cross Sections for
$C^{4+} + H \rightarrow C^{4+} + H^{+} + e^{-}$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
2.0E+04	1.96E+08	2.07E-16
4.0E+04	2.78E+08	4.95E-16
7.0E+04	3.68E+08	8.51E-16
1.0E+05	4.39E+08	9.88E-16
2.0E+05	6.21E+08	8.22E-16
4.0E+05	8.78E+08	5.66E-16
7.0E+05	1.16E+09	3.79E-16
1.0E+06	1.39E+09	2.85E-16
2.0E+06	1.96E+09	1.57E-16
4.0E+06	2.77E+09	8.79E-17
7.0E+06	3.65E+09	5.50E-17
1.0E+07	4.36E+09	4.20E-17

References: E.65, E.66, T.8, T.9, T.51, T.52

Accuracy: 15% for $E \leq 4\text{x}10^5$ eV/amu; 20% for $E > 4\text{x}10^5$ eV/amu

Note: In the region $E \leq 4\text{x}10^5$ eV/amu the recommended cross section represents the experimental data, [E.65], [E.66], extended to energies below $5\text{x}10^4$ eV/amu by the calculations of Ref. [T.52]. In the region $5\text{x}10^4 \leq E\text{(eV/amu)} \leq 4\text{x}10^5$ these measurements and calculations coincide. For $E > 4\text{x}10^5$ eV/amu, the cross section is given by the semi-empirical formula [T.51], the results of which coincide with the experimental data down to $E \simeq 4\text{x}10^4$ eV/amu (see sect. 2.1.1).

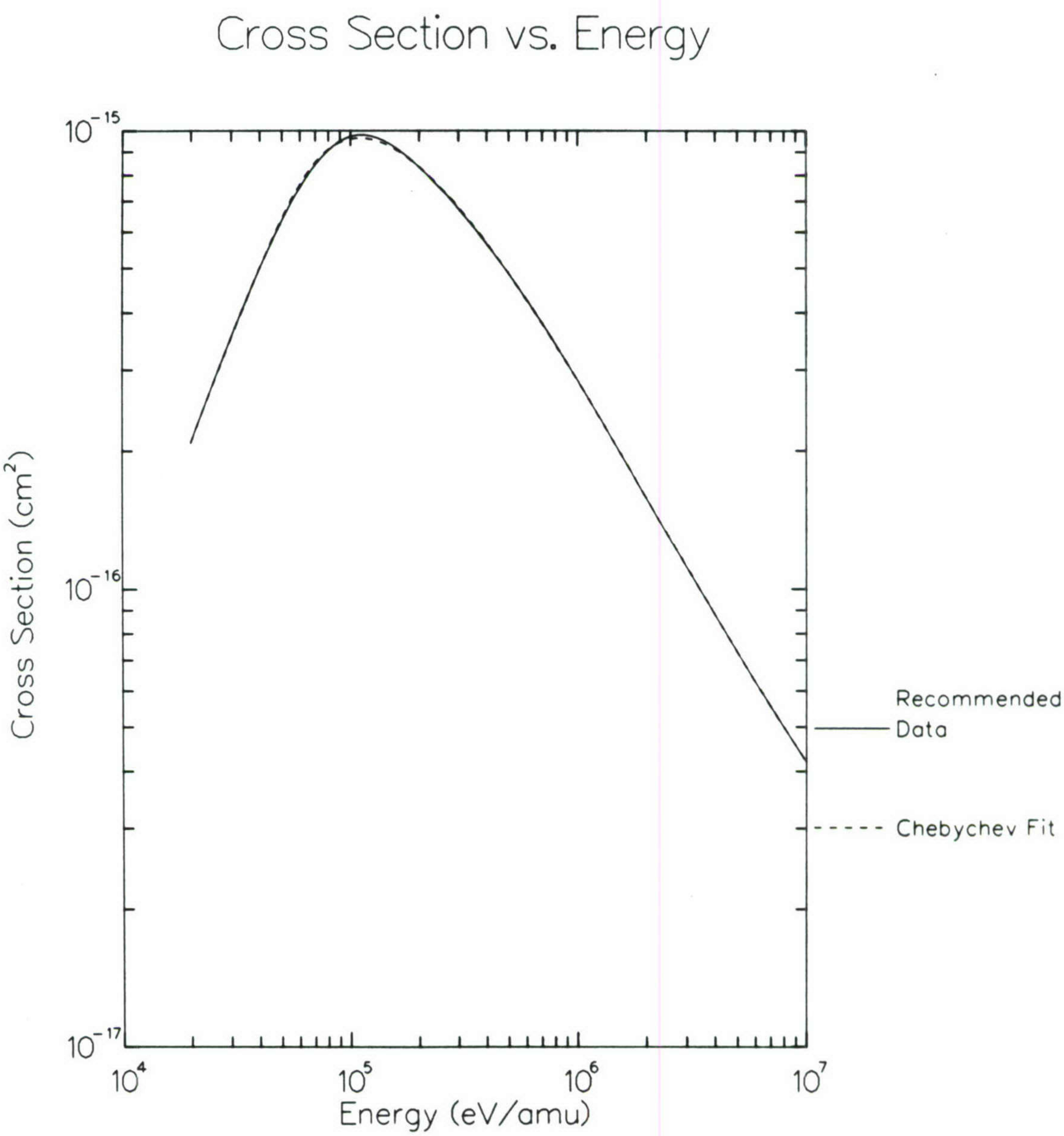
For Chebychev fits of the above cross sections it is necessary to use the following parameters.
E_{min} = 2.0E+04 eV/amu, E_{max} = 1.0E+07 eV/amu

Chebychev Fitting Parameters for Cross Sections

C1	C2	C3	C4	C5	C6	C7	C8	C9
6.918E-16	-2.211E-16	-2.632E-16	2.392E-16	-2.665E-17	-7.452E-17	6.234E-17	-2.614E-17	6.095E-18

The fit represents the above cross sections with an rms deviation of 1.3%.
The maximum deviation is 2.5% at 7.0E+04 eV/amu.
See appendix for Chebychev fit details.

$C^{4+} + H \rightarrow C^{4+} + H^{+} + e^{-}$



Ionization Rate Coefficients for
$H + C^{4+} \rightarrow C^{4+} + H^{+} + e^{-}$

Beam - Maxwellian Rate Coefficients (cm^3/s)

C^{4+} Temp. (eV)	H Energy (eV/amu) 20000.	40000.	70000.	100000.	200000.	400000.	500000.
1.0E+00	2.04E-08**	1.38E-07	3.13E-07	4.34E-07	5.11E-07	4.97E-07	4.79E-07
2.0E+00	2.05E-08**	1.38E-07	3.13E-07	4.34E-07	5.11E-07	4.97E-07	4.79E-07
4.0E+00	2.06E-08*	1.38E-07	3.13E-07	4.34E-07	5.11E-07	4.97E-07	4.79E-07
7.0E+00	2.06E-08*	1.38E-07	3.13E-07	4.34E-07	5.11E-07	4.97E-07	4.79E-07
1.0E+01	2.07E-08*	1.38E-07	3.13E-07	4.34E-07	5.11E-07	4.97E-07	4.79E-07
2.0E+01	2.08E-08*	1.38E-07	3.13E-07	4.34E-07	5.11E-07	4.97E-07	4.79E-07
4.0E+01	2.11E-08*	1.38E-07	3.13E-07	4.34E-07	5.11E-07	4.97E-07	4.79E-07
7.0E+01	2.13E-08*	1.38E-07	3.12E-07	4.34E-07	5.11E-07	4.97E-07	4.79E-07
1.0E+02	2.15E-08*	1.38E-07	3.12E-07	4.34E-07	5.11E-07	4.97E-07	4.79E-07
2.0E+02	2.20E-08*	1.38E-07	3.12E-07	4.34E-07	5.11E-07	4.97E-07	4.79E-07
4.0E+02	2.27E-08*	1.38E-07	3.12E-07	4.34E-07	5.12E-07	4.97E-07	4.79E-07
7.0E+02	2.36E-08*	1.38E-07	3.12E-07	4.34E-07	5.12E-07	4.97E-07	4.79E-07
1.0E+03	2.43E-08*	1.38E-07	3.12E-07	4.34E-07	5.12E-07	4.97E-07	4.79E-07
2.0E+03	2.61E-08*	1.39E-07	3.12E-07	4.33E-07	5.13E-07	4.97E-07	4.79E-07
4.0E+03	2.90E-08*	1.41E-07	3.12E-07	4.33E-07	5.13E-07	4.97E-07	4.79E-07
7.0E+03	3.26E-08*	1.43E-07	3.12E-07	4.33E-07	5.14E-07	4.97E-07	4.78E-07
1.0E+04	3.57E-08*	1.46E-07	3.13E-07	4.32E-07	5.15E-07	4.97E-07	4.77E-07
2.0E+04	4.48E-08*	1.53E-07	3.14E-07	4.30E-07	5.15E-07	4.97E-07	4.78E-07

Accuracy: * - Possible Error Greater Than 10%
** - Possible Error Greater Than 100%

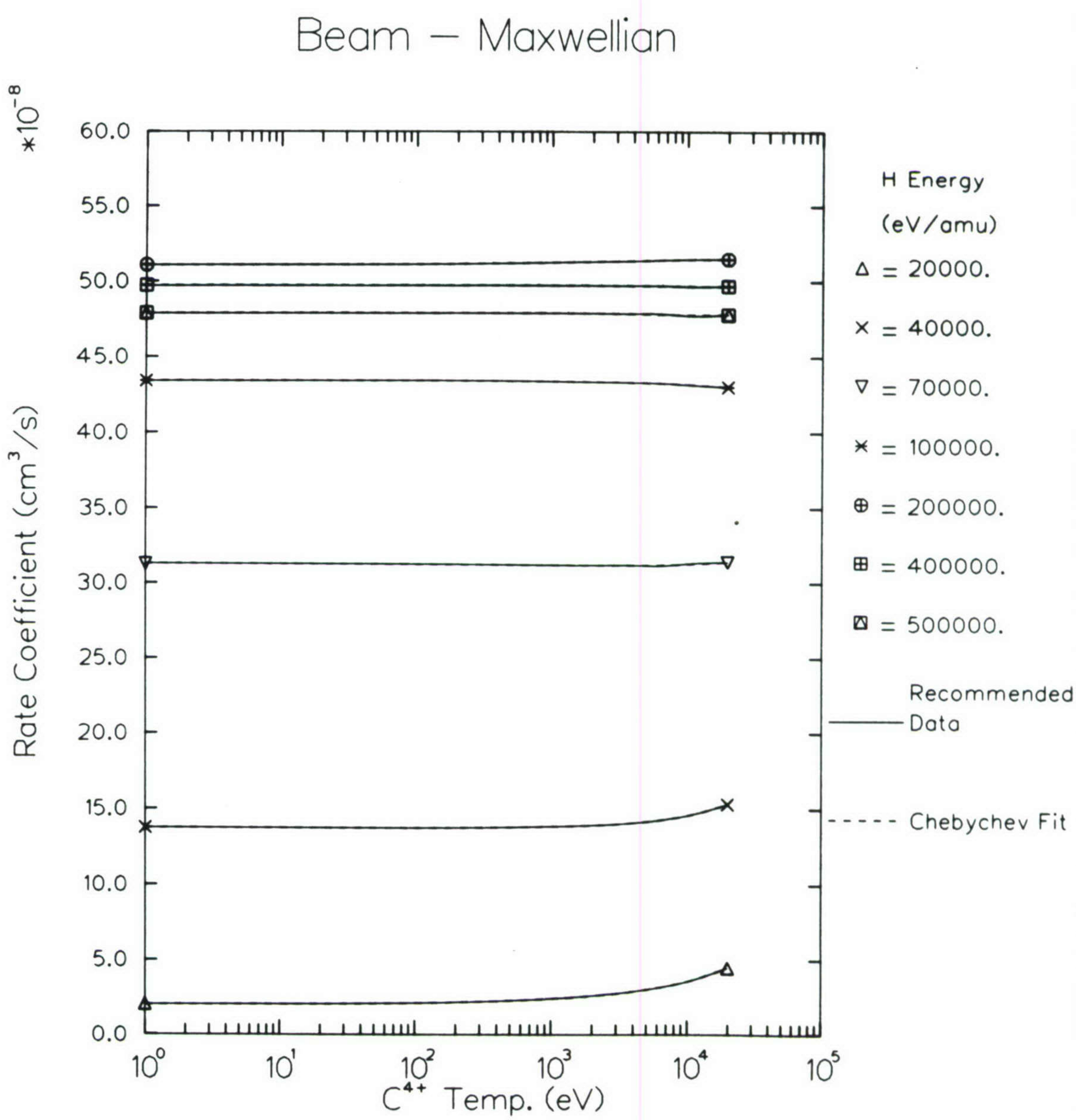
Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

Chebychev Fitting Parameters for Rate Coefficients

H Energy (eV/amu)	C1	C2	C3	C4	C5	C6	C7
20000.	5.239E-08	9.355E-09	5.321E-09	2.434E-09	9.681E-10	3.451E-10	1.077E-10
40000.	2.810E-07	5.291E-09	3.756E-09	2.174E-09	1.032E-09	3.993E-10	1.232E-10
70000.	6.253E-07	1.895E-10	5.615E-10	5.112E-10	2.825E-10	1.060E-10	1.338E-11
100000.	8.664E-07	-1.306E-09	-8.737E-10	-4.686E-10	-2.027E-10	-6.816E-11	-9.684E-12
200000.	1.024E-06	2.119E-09	7.854E-10	6.704E-11	-1.090E-10	-8.938E-11	-5.864E-11
400000.	9.942E-07	-6.176E-11	-1.075E-10	-7.150E-11	-1.636E-11	2.236E-11	5.217E-11
500000.	9.570E-07	-3.416E-10	-2.506E-10	-9.538E-11	1.850E-11	7.722E-11	1.237E-10

See appendix for Chebychev fit details.

$H + C^{4+} \rightarrow C^{4+} + H^{+} + e^{-}$



Ionization Cross Sections for
$C^{5+} + H \rightarrow C^{5+} + H^{+} + e^{-}$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
2.8E+04	2.32E+08	2.11E-16
4.0E+04	2.78E+08	3.78E-16
7.0E+04	3.68E+08	9.34E-16
1.0E+05	4.39E+08	1.23E-15
1.3E+05	5.01E+08	1.33E-15
2.0E+05	6.21E+08	1.17E-15
4.0E+05	8.78E+08	7.81E-16
7.0E+05	1.16E+09	5.60E-16
1.0E+06	1.39E+09	4.40E-16
2.0E+06	1.96E+09	2.60E-16
4.0E+06	2.77E+09	1.44E-16
7.0E+06	3.65E+09	8.95E-17
1.0E+07	4.36E+09	6.51E-17

References: E.65, T.8, T.9, T.17, T.51, T.52

Accuracy: 30% for $E \leq 7x10^4$ eV/amu; 20% for $7x10^4 < E(eV/amu) < 5x10^5$; 30% for $E \geq 5x10^5$ eV/amu

Note: The cross section in the region below $E = 5x10^5$ eV/amu is based on the experimental data [E.65], calculations in Ref. [T.52], and the semi-empirical scaling formula [T.51], which all agree within the indicated uncertainty. For $E > 5x10^5$ eV/amu, the cross section is given by the semi-empirical scaling formula [T.51] (see also sect. 2.1.1).

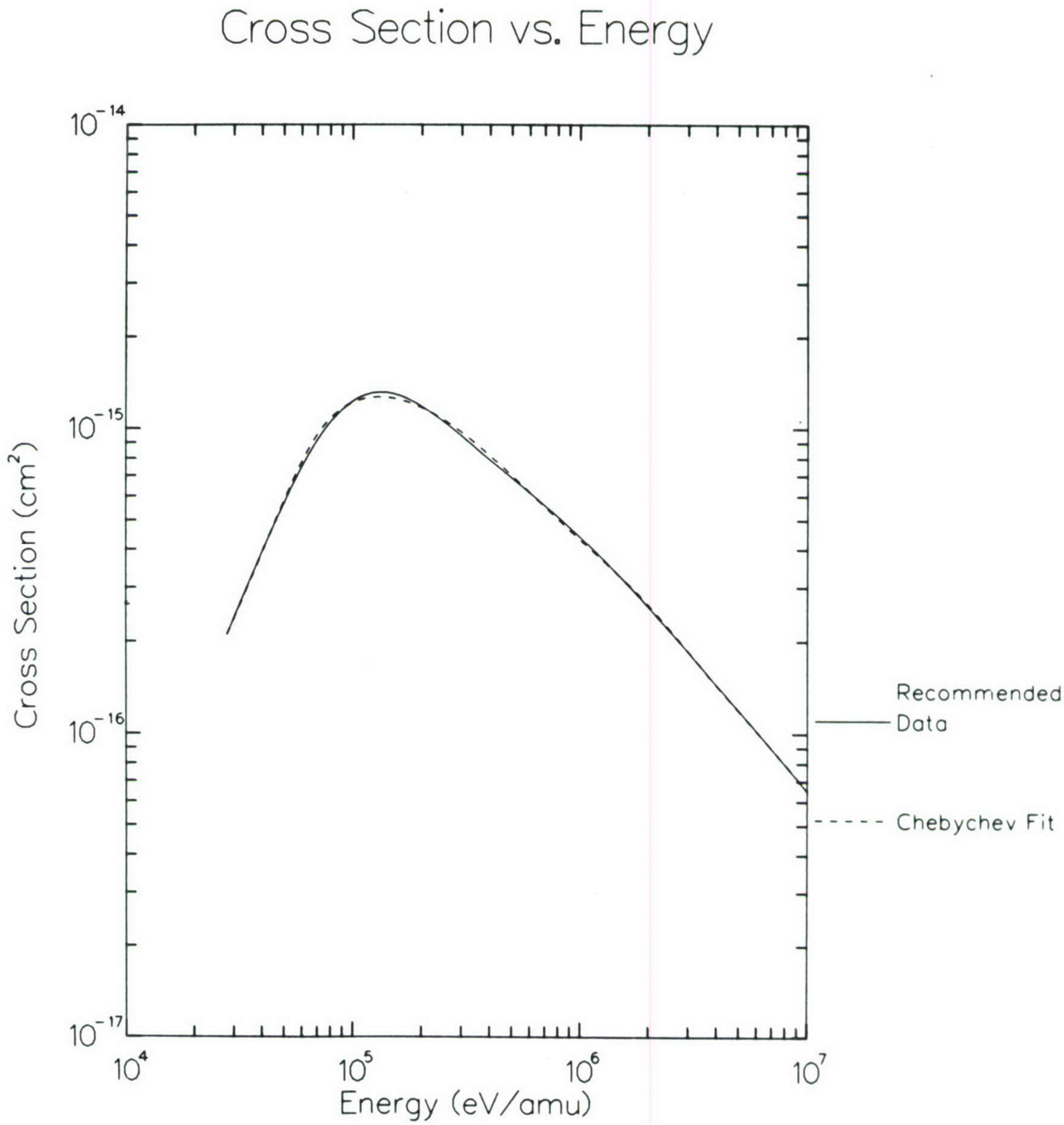
For Chebychev fits of the above cross sections it is necessary to use the following parameters.
E_{min} = 2.8E+04 eV/amu, E_{max} = 1.0E+07 eV/amu

Chebychev Fitting Parameters for Cross Sections

C1	C2	C3	C4	C5	C6	C7	C8	C9
9.368E-16	-2.869E-16	-3.435E-16	3.156E-16	-6.229E-17	-7.283E-17	7.576E-17	-2.898E-17	-1.860E-19

The fit represents the above cross sections with an rms deviation of 2.5%.
The maximum deviation is 4.6% at 7.0E+04 eV/amu.
See appendix for Chebychev fit details.

$C^{5+} + H \rightarrow C^{5+} + H^{+} + e^{-}$



Ionization Rate Coefficients for
$H + C^{5+} \rightarrow C^{5+} + H^+ + e^-$

Beam - Maxwellian Rate Coefficients (cm^3/s)

C^{5+} Temp. (eV)	H Energy (eV/amu) 20000.	40000.	70000.	100000.	200000.	400000.	500000.
1.0E+00	1.19E-08**	1.05E-07	3.43E-07	5.40E-07	7.27E-07	6.86E-07	6.72E-07
2.0E+00	1.19E-08**	1.05E-07	3.43E-07	5.40E-07	7.27E-07	6.86E-07	6.72E-07
4.0E+00	1.19E-08*	1.05E-07	3.43E-07	5.40E-07	7.27E-07	6.86E-07	6.72E-07
7.0E+00	1.20E-08*	1.05E-07	3.43E-07	5.40E-07	7.27E-07	6.86E-07	6.72E-07
1.0E+01	1.20E-08*	1.05E-07	3.43E-07	5.40E-07	7.27E-07	6.86E-07	6.72E-07
2.0E+01	1.21E-08*	1.05E-07	3.43E-07	5.40E-07	7.27E-07	6.86E-07	6.72E-07
4.0E+01	1.23E-08*	1.05E-07	3.43E-07	5.40E-07	7.27E-07	6.86E-07	6.72E-07
7.0E+01	1.24E-08*	1.05E-07	3.42E-07	5.40E-07	7.27E-07	6.86E-07	6.72E-07
1.0E+02	1.25E-08*	1.05E-07	3.42E-07	5.40E-07	7.27E-07	6.86E-07	6.72E-07
2.0E+02	1.29E-08*	1.05E-07	3.42E-07	5.40E-07	7.28E-07	6.86E-07	6.72E-07
4.0E+02	1.34E-08*	1.06E-07	3.42E-07	5.41E-07	7.28E-07	6.87E-07	6.72E-07
7.0E+02	1.39E-08*	1.06E-07	3.41E-07	5.41E-07	7.28E-07	6.87E-07	6.72E-07
1.0E+03	1.44E-08*	1.06E-07	3.41E-07	5.41E-07	7.29E-07	6.87E-07	6.72E-07
2.0E+03	1.57E-08*	1.07E-07	3.41E-07	5.41E-07	7.29E-07	6.87E-07	6.72E-07
4.0E+03	1.78E-08*	1.10E-07	3.42E-07	5.41E-07	7.30E-07	6.88E-07	6.72E-07
7.0E+03	2.04E-08*	1.14E-07	3.43E-07	5.41E-07	7.30E-07	6.88E-07	6.72E-07
1.0E+04	2.28E-08*	1.17E-07	3.45E-07	5.41E-07	7.30E-07	6.88E-07	6.70E-07
2.0E+04	3.02E-08*	1.30E-07	3.50E-07	5.40E-07	7.29E-07	6.89E-07	6.72E-07

Accuracy: * - Possible Error Greater Than 10%
** - Possible Error Greater Than 100%

Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

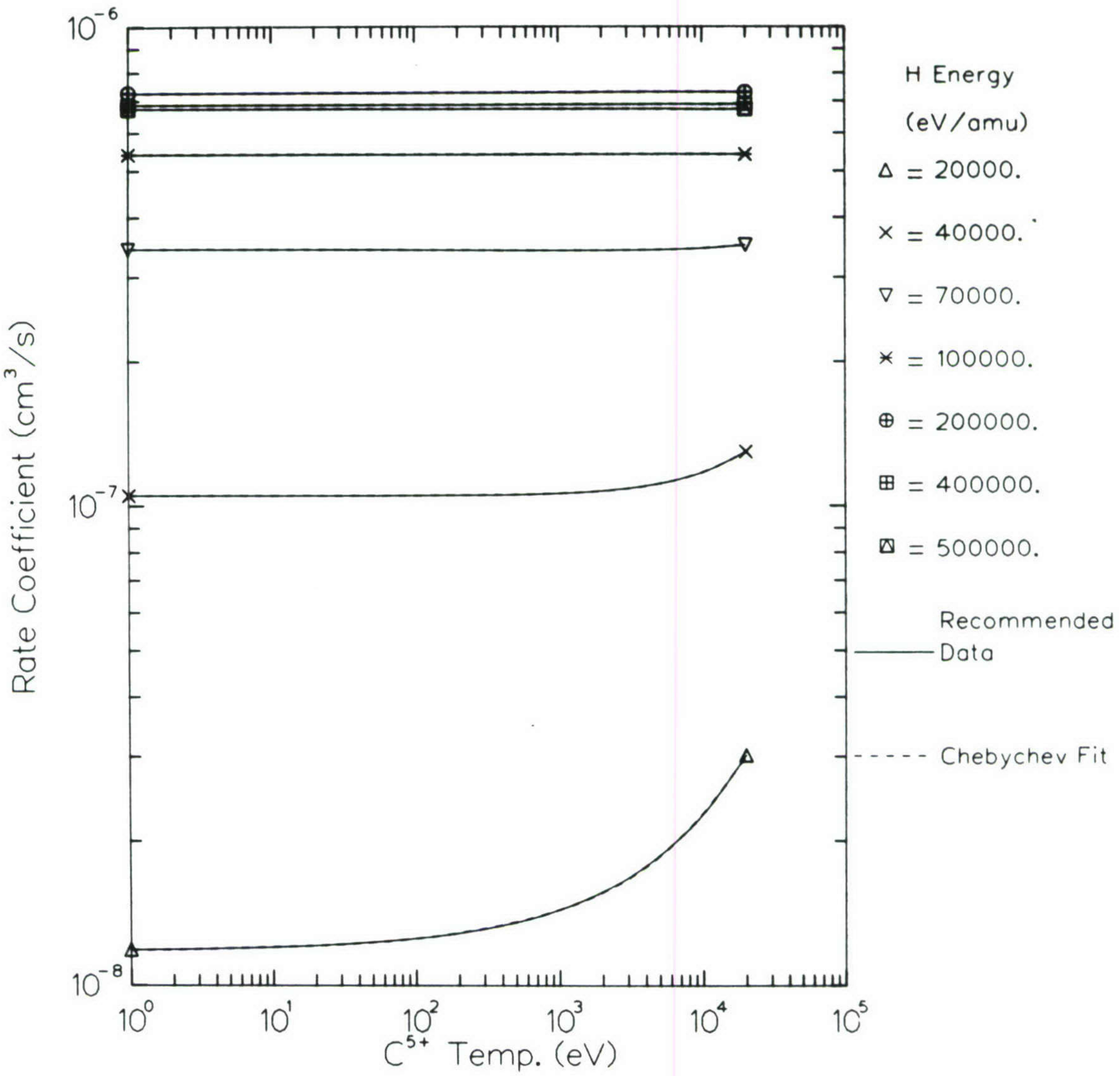
Chebychev Fitting Parameters for Rate Coefficients

H Energy (eV/amu)	C1	C2	C3	C4	C5	C6	C7
20000.	3.201E-08	6.835E-09	4.044E-09	1.975E-09	8.566E-10	3.359E-10	1.149E-10
40000.	2.191E-07	8.131E-09	5.808E-09	3.422E-09	1.677E-09	6.839E-10	2.342E-10
70000.	6.869E-07	1.335E-09	2.121E-09	1.765E-09	9.691E-10	3.804E-10	1.038E-10
100000.	1.081E-06	1.954E-10	-3.435E-11	-1.060E-10	-7.466E-11	-3.626E-11	-2.736E-11
200000.	1.456E-06	1.658E-09	3.272E-10	-2.746E-10	-3.031E-10	-1.787E-10	-9.923E-11
400000.	1.374E-06	1.350E-09	5.887E-10	1.837E-10	6.476E-11	5.421E-11	7.819E-11
500000.	1.344E-06	-2.684E-10	-2.006E-10	-4.235E-11	7.364E-11	1.307E-10	1.849E-10

See appendix for Chebychev fit details.

$H + C^{5+} \rightarrow C^{5+} + H^{+} + e^{-}$

Beam – Maxwellian



Ionization Cross Sections for
$C^{6+} + H \rightarrow C^{6+} + H^{+} + e^{-}$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
2.9E+04	2.37E+08	1.68E-16
4.0E+04	2.78E+08	3.66E-16
7.0E+04	3.68E+08	9.04E-16
1.0E+05	4.39E+08	1.28E-15
2.0E+05	6.21E+08	1.56E-15
4.0E+05	8.78E+08	1.10E-15
7.0E+05	1.16E+09	7.63E-16
1.0E+06	1.39E+09	5.99E-16
2.0E+06	1.96E+09	3.61E-16
4.0E+06	2.77E+09	2.03E-16
7.0E+06	3.65E+09	1.24E-16
1.0E+07	4.36E+09	9.09E-17
2.2E+07	6.40E+09	4.27E-17

References: E.65, T.8, T.9, T.23, T.24, T.51, T.53, T.54, T.55, T.56, T.57, T.58, T.62

Accuracy: 30% for $E < 2x10^5$ eV/amu; 20% for $2x10^5 \leq E(eV/amu) \leq 1x10^6$; 30% for $E > 1x10^6$ eV/amu

Note: In the region $2x10^5 \leq E(eV/amu) \leq 1x10^6$, the cross section is constructed on the basis of continuum distorted wave calculations [T.58], which coincide with the experimental data point at $E \simeq 4x10^5$ eV/amu [E.65], and for $E \geq 5x10^5$ eV/amu, the semi-empirical scaling formula [T.51] was used. For energies above and below this region, the cross section is constructed on the basis of the semi-empirical scaling formula [T.51], (see also sect. 2.1.1).

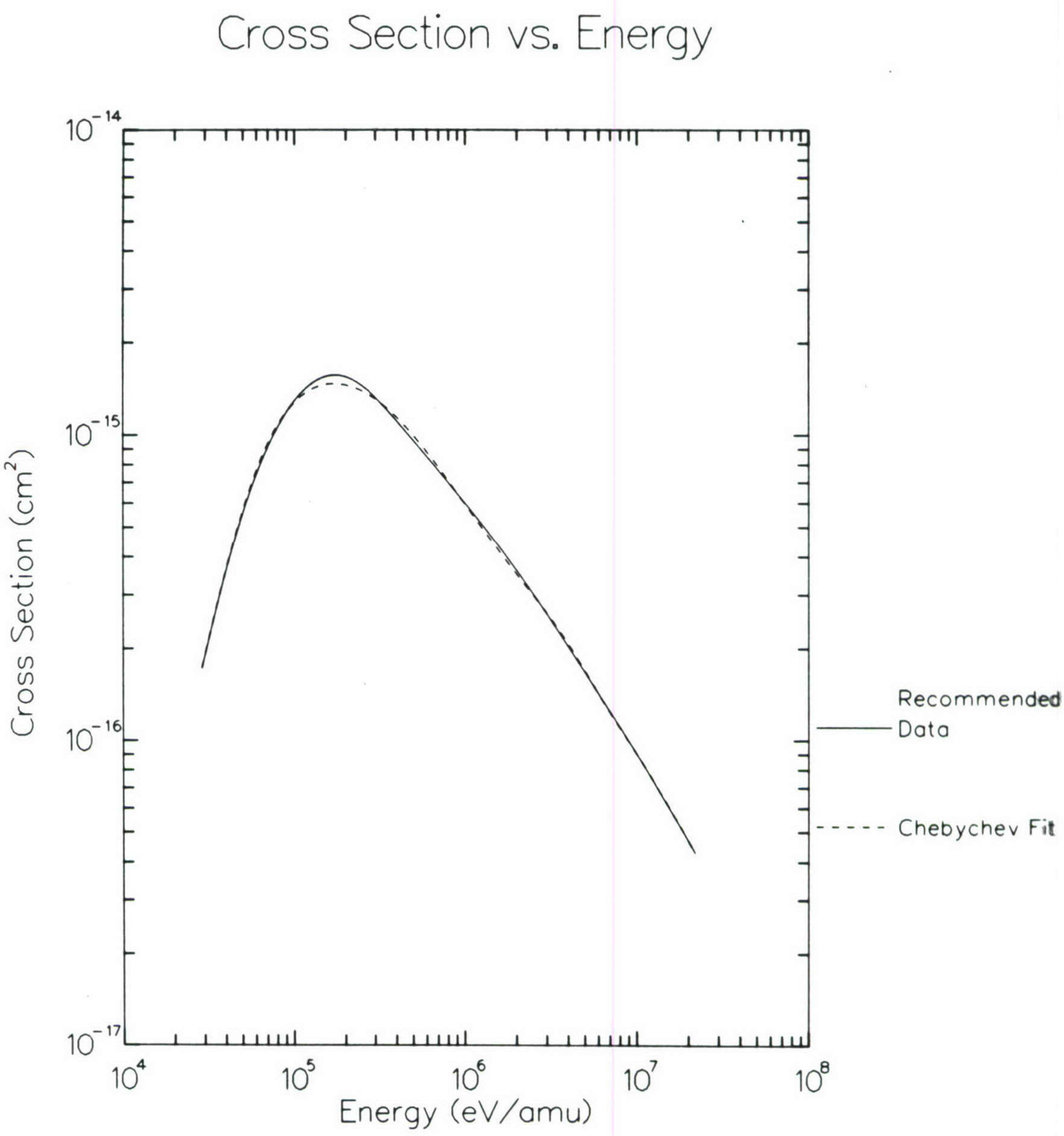
For Chebychev fits of the above cross sections it is necessary to use the following parameters.
E_{min} = 2.9E+04 eV/amu, E_{max} = 2.2E+07 eV/amu

Chebychev Fitting Parameters for Cross Sections

C1	C2	C3	C4	C5	C6	C7	C8	C9
1.010E-15	-3.398E-16	-3.809E-16	3.938E-16	-8.048E-17	-9.641E-17	7.946E-17	-2.044E-17	-1.767E-17

The fit represents the above cross sections with an rms deviation of 3.1%.
The maximum deviation is 4.3% at 7.0E+04 eV/amu.
See appendix for Chebychev fit details.

$C^{6+} + H \rightarrow C^{6+} + H^{+} + e^{-}$



Ionization Rate Coefficients for
$H + C^{6+} \rightarrow C^{6+} + H^{+} + e^{-}$

Beam - Maxwellian Rate Coefficients (cm^3/s)

C^{6+} Temp. (eV)	H Energy (eV/amu) 20000.	40000.	70000.	100000.	200000.	400000.	500000.
1.0E+00	6.94E-09**	1.02E-07	3.32E-07	5.62E-07	9.69E-07	9.66E-07	9.42E-07
2.0E+00	6.96E-09**	1.02E-07	3.32E-07	5.62E-07	9.69E-07	9.66E-07	9.42E-07
4.0E+00	6.99E-09*	1.02E-07	3.32E-07	5.62E-07	9.69E-07	9.66E-07	9.42E-07
7.0E+00	7.03E-09*	1.02E-07	3.32E-07	5.62E-07	9.69E-07	9.66E-07	9.42E-07
1.0E+01	7.05E-09*	1.02E-07	3.32E-07	5.62E-07	9.69E-07	9.66E-07	9.42E-07
2.0E+01	7.13E-09*	1.02E-07	3.32E-07	5.62E-07	9.69E-07	9.66E-07	9.42E-07
4.0E+01	7.23E-09*	1.02E-07	3.32E-07	5.62E-07	9.69E-07	9.67E-07	9.42E-07
7.0E+01	7.35E-09*	1.02E-07	3.32E-07	5.62E-07	9.69E-07	9.67E-07	9.42E-07
1.0E+02	7.44E-09*	1.02E-07	3.33E-07	5.62E-07	9.69E-07	9.67E-07	9.42E-07
2.0E+02	7.69E-09*	1.02E-07	3.33E-07	5.62E-07	9.69E-07	9.67E-07	9.42E-07
4.0E+02	8.06E-09*	1.02E-07	3.33E-07	5.62E-07	9.69E-07	9.68E-07	9.42E-07
7.0E+02	8.49E-09*	1.02E-07	3.33E-07	5.63E-07	9.69E-07	9.68E-07	9.42E-07
1.0E+03	8.86E-09*	1.03E-07	3.34E-07	5.63E-07	9.69E-07	9.68E-07	9.42E-07
2.0E+03	9.89E-09*	1.04E-07	3.35E-07	5.63E-07	9.69E-07	9.69E-07	9.42E-07
4.0E+03	1.16E-08*	1.06E-07	3.37E-07	5.64E-07	9.69E-07	9.70E-07	9.42E-07
7.0E+03	1.40E-08*	1.10E-07	3.40E-07	5.65E-07	9.68E-07	9.71E-07	9.41E-07
1.0E+04	1.62E-08*	1.14E-07	3.43E-07	5.66E-07	9.67E-07	9.71E-07	9.39E-07
2.0E+04	2.39E-08*	1.27E-07	3.52E-07	5.70E-07	9.64E-07	9.74E-07	9.41E-07

Accuracy: * - Possible Error Greater Than 10%
** - Possible Error Greater Than 100%

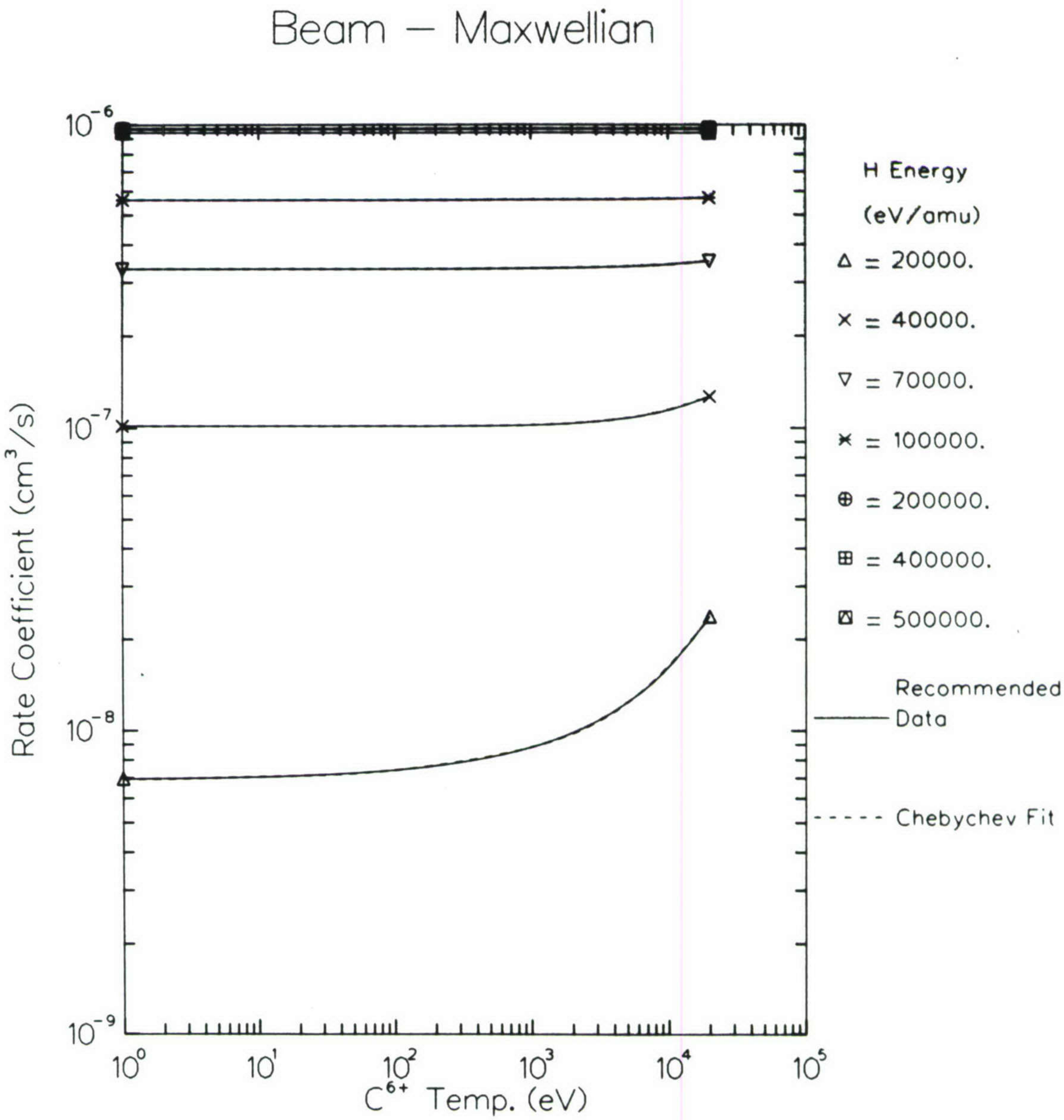
Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

Chebychev Fitting Parameters for Rate Coefficients

H Energy (eV/amu)	C1	C2	C3	C4	C5	C6	C7
20000.	2.102E-08	6.005E-09	3.751E-09	1.985E-09	9.410E-10	3.981E-10	1.414E-10
40000.	2.124E-07	8.258E-09	6.093E-09	3.595E-09	1.706E-09	6.463E-10	1.986E-10
70000.	6.723E-07	6.794E-09	4.559E-09	2.532E-09	1.189E-09	4.732E-10	1.627E-10
100000.	1.128E-06	2.698E-09	1.885E-09	1.080E-09	5.283E-10	2.123E-10	7.842E-11
200000.	1.937E-06	-1.327E-09	-1.214E-09	-8.731E-10	-4.936E-10	-2.347E-10	-1.238E-10
400000.	1.937E-06	3.397E-09	1.460E-09	3.978E-10	7.969E-11	5.090E-11	9.591E-11
500000.	1.883E-06	-6.116E-10	-4.488E-10	-1.585E-10	5.388E-11	1.619E-10	2.500E-10

See appendix for Chebychev fit details.

$H + C^{6+} \rightarrow C^{6+} + H^{+} + e^{-}$



Ionization Cross Sections for
$O^{+} + H \rightarrow O^{+} + H^{+} + e^{-}$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
7.0E+03	1.16E+08	5.06E-17
1.0E+04	1.39E+08	6.95E-17
2.0E+04	1.96E+08	1.15E-16
4.0E+04	2.78E+08	1.44E-16
7.0E+04	3.68E+08	1.36E-16
1.0E+05	4.39E+08	1.18E-16
2.0E+05	6.21E+08	7.70E-17
4.0E+05	8.78E+08	4.57E-17
7.0E+05	1.16E+09	2.91E-17
1.0E+06	1.39E+09	2.16E-17
2.0E+06	1.96E+09	1.18E-17
4.0E+06	2.77E+09	6.12E-18
7.0E+06	3.65E+09	3.63E-18
1.0E+07	4.36E+09	2.60E-18

References: T.9, T.51, T.53

Accuracy: 50% for E < $1x10^5$ eV/amu; 40% for E $\geq$ $1x10^5$ eV/amu

Note: No experimental data are available for this reaction. The calculations of Refs. [T.51] and [T.53] agree in the region $3x10^4 \leq E(eV/amu) \leq 2x10^5$, as well as with the result of Ref. [T.9] at E = $1x10^5$ eV/amu. The recommended cross section has been constructed by using the formulae from [T.51] and [T.53] as well as the empirical scaling for the maximum cross section, which follows from the experimental data for O^{q+} + H (q = 2-5) ionization, (see also sect. 2.1.1).

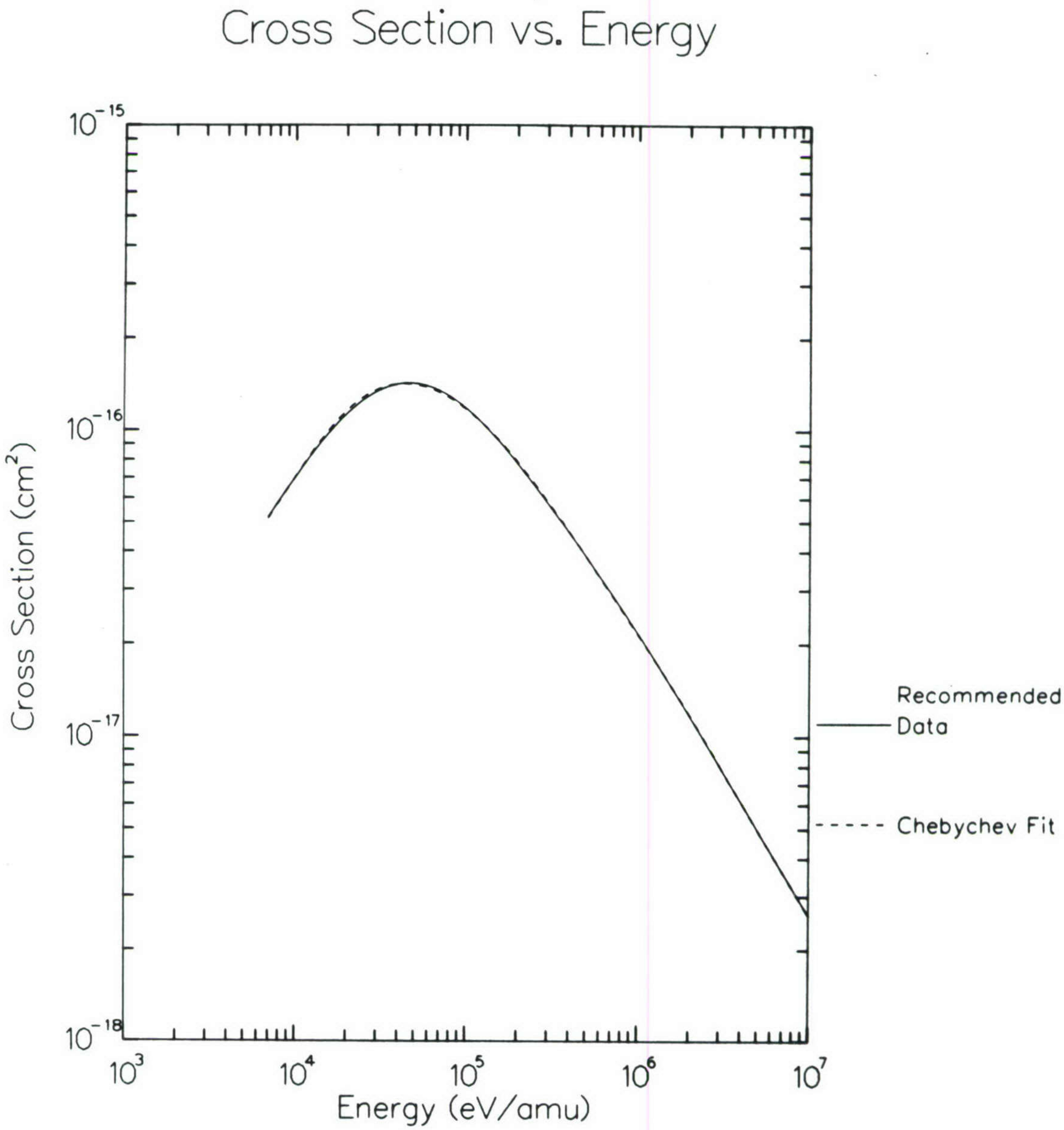
For Chebychev fits of the above cross sections it is necessary to use the following parameters.
E_{min} = 7.0E+03 eV/amu, E_{max} = 1.0E+07 eV/amu

Chebychev Fitting Parameters for Cross Sections

C1	C2	C3	C4	C5	C6	C7	C8	C9
1.098E-16	-5.064E-17	-2.503E-17	3.449E-17	-8.837E-18	-6.769E-18	6.053E-18	-1.179E-18	-4.127E-19

The fit represents the above cross sections with an rms deviation of 1.7%.
The maximum deviation is 3.3% at 2.0E+04 eV/amu.
See appendix for Chebychev fit details.

$O^+ + H \rightarrow O^+ + H^+ + e^-$



Ionization Rate Coefficients for
$H + O^{+} \rightarrow O^{+} + H^{+} + e^{-}$

Beam - Maxwellian Rate Coefficients (cm^3/s)

O^{+} Temp. (eV)	H Energy (eV/amu) 10000.	20000.	40000.	70000.	100000.	200000.	500000.
1.0E+00	9.65E-09	2.26E-08	4.00E-08	5.00E-08	5.18E-08	4.78E-08	3.76E-08
2.0E+00	9.65E-09	2.26E-08	4.00E-08	5.00E-08	5.18E-08	4.78E-08	3.76E-08
4.0E+00	9.65E-09	2.26E-08	4.00E-08	5.00E-08	5.18E-08	4.78E-08	3.76E-08
7.0E+00	9.66E-09	2.26E-08	4.00E-08	5.00E-08	5.18E-08	4.78E-08	3.76E-08
1.0E+01	9.66E-09	2.26E-08	4.00E-08	5.00E-08	5.18E-08	4.78E-08	3.76E-08
2.0E+01	9.66E-09	2.26E-08	4.00E-08	5.00E-08	5.18E-08	4.78E-08	3.76E-08
4.0E+01	9.66E-09	2.26E-08	4.00E-08	5.00E-08	5.18E-08	4.78E-08	3.76E-08
7.0E+01	9.66E-09	2.26E-08	4.00E-08	5.00E-08	5.18E-08	4.78E-08	3.76E-08
1.0E+02	9.67E-09	2.26E-08	4.00E-08	5.00E-08	5.18E-08	4.78E-08	3.76E-08
2.0E+02	9.68E-09	2.26E-08	4.00E-08	5.00E-08	5.18E-08	4.78E-08	3.76E-08
4.0E+02	9.71E-09	2.26E-08	4.00E-08	5.00E-08	5.18E-08	4.78E-08	3.76E-08
7.0E+02	9.74E-09	2.26E-08	4.00E-08	5.00E-08	5.18E-08	4.79E-08	3.76E-08
1.0E+03	9.78E-09	2.26E-08	4.00E-08	5.00E-08	5.18E-08	4.79E-08	3.76E-08
2.0E+03	9.83E-09	2.27E-08	4.00E-08	4.99E-08	5.18E-08	4.79E-08	3.76E-08
4.0E+03	9.88E-09	2.28E-08	3.99E-08	4.99E-08	5.18E-08	4.79E-08	3.76E-08
7.0E+03	1.01E-08	2.30E-08	3.98E-08	4.98E-08	5.18E-08	4.78E-08	3.76E-08
1.0E+04	1.03E-08	2.32E-08	3.99E-08	4.97E-08	5.18E-08	4.79E-08	3.76E-08
2.0E+04	1.14E-08	2.38E-08	3.99E-08	4.96E-08	5.16E-08	4.79E-08	3.76E-08

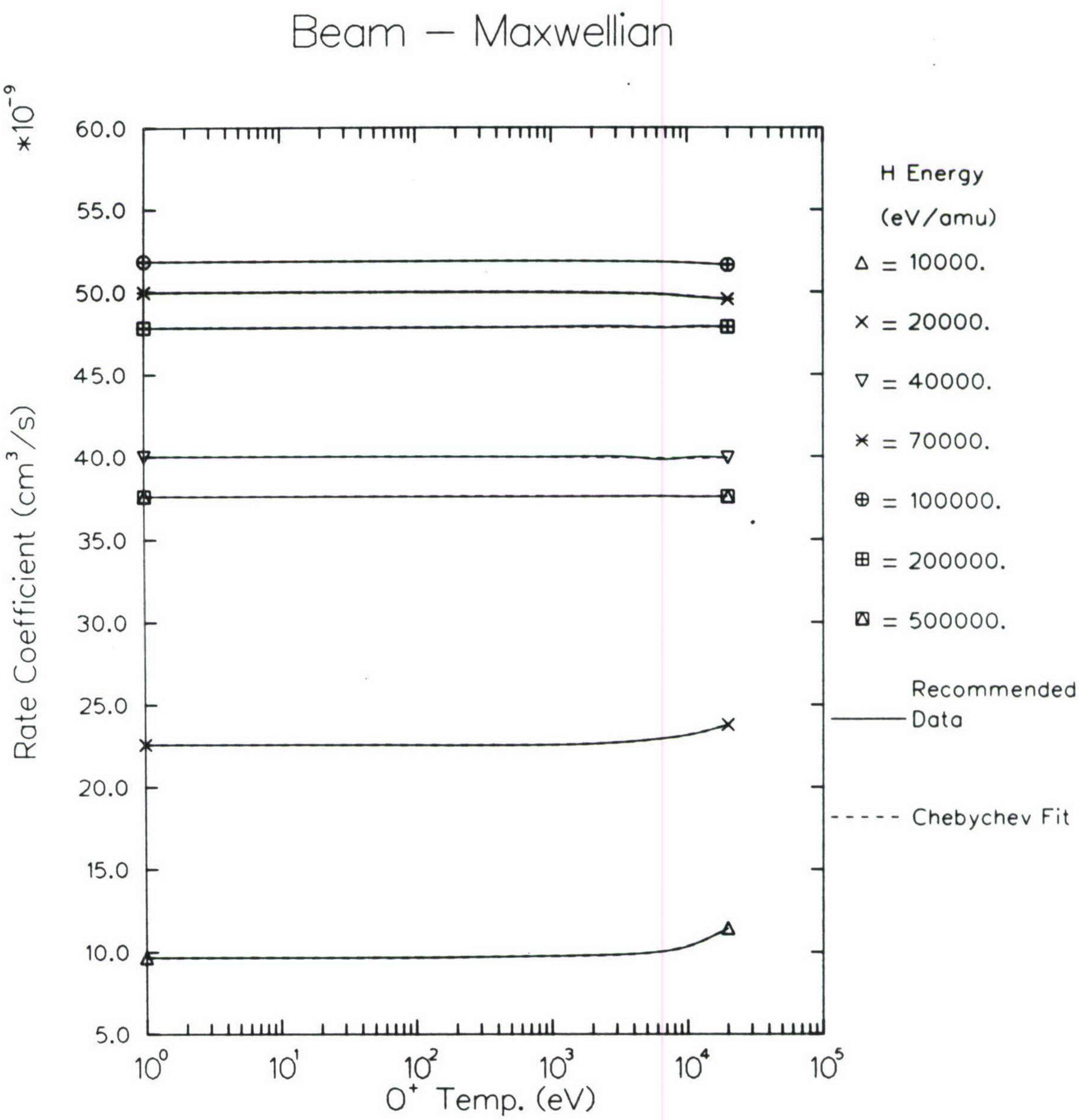
Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

Chebychev Fitting Parameters for Rate Coefficients

H Energy (eV/amu)	C1	C2	C3	C4	C5	C6	C7
10000.	1.990E-08	5.348E-10	3.876E-10	2.566E-10	1.617E-10	9.660E-11	5.205E-11
20000.	4.560E-08	3.886E-10	2.964E-10	1.796E-10	8.599E-11	3.251E-11	9.997E-12
40000.	7.993E-08	-5.726E-11	-2.460E-11	7.756E-13	1.168E-11	1.263E-11	9.490E-12
70000.	9.980E-08	-1.436E-10	-1.041E-10	-5.955E-11	-2.662E-11	-8.901E-12	-1.029E-12
100000.	1.036E-07	-5.739E-11	-5.262E-11	-3.685E-11	-1.983E-11	-8.395E-12	-2.797E-12
200000.	9.569E-08	2.192E-11	2.930E-12	-2.170E-12	4.015E-13	2.931E-12	3.100E-12
500000.	7.519E-08	-7.222E-12	-5.306E-12	-2.283E-12	-5.542E-14	1.132E-12	2.049E-12

See appendix for Chebychev fit details.

$H + O^{+} \rightarrow O^{+} + H^{+} + e^{-}$



Ionization Cross Sections for
$O^{2+} + H \to O^{2+} + H^{+} + e^{-}$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
1.0E+04	1.39E+08	1.25E-16
2.0E+04	1.96E+08	2.27E-16
4.0E+04	2.78E+08	4.14E-16
7.0E+04	3.68E+08	4.28E-16
1.0E+05	4.39E+08	3.88E-16
2.0E+05	6.21E+08	2.84E-16
4.0E+05	8.78E+08	1.82E-16
7.0E+05	1.16E+09	1.22E-16
1.0E+06	1.39E+09	9.11E-17
2.0E+06	1.96E+09	5.02E-17
4.0E+06	2.77E+09	2.65E-17
7.0E+06	3.65E+09	1.57E-17
1.0E+07	4.36E+09	1.12E-17

References: E.65, E.66, T.9, T.51, T.52, T.53

Accuracy: 15% for $E \leq 3x10^5$ eV/amu; 30% for $E > 3x10^5$ eV/amu

Notes: (1) In the region below $E = 3x10^5$ eV/amu, the recommended cross section represents the experimental data, [E.65], [E.66]. Above this energy, the cross section is given by the semi-empirical scaling formula [T.51], normalized to the experimental values in the region around the cross section maximum, and preserving the high-energy ($\gtrsim 10^7$ eV/amu) Bethe-Born values, (see also section 2.1.1).

(2) In the region below $1x10^4$ eV/amu, the presented cross section may be smoothly extrapolated to the values obtained from the theory of Ref. [T.53].

For Chebychev fits of the above cross sections it is necessary to use the following parameters.
E_{min} = 1.0E+04 eV/amu, E_{max} = 1.0E+07 eV/amu

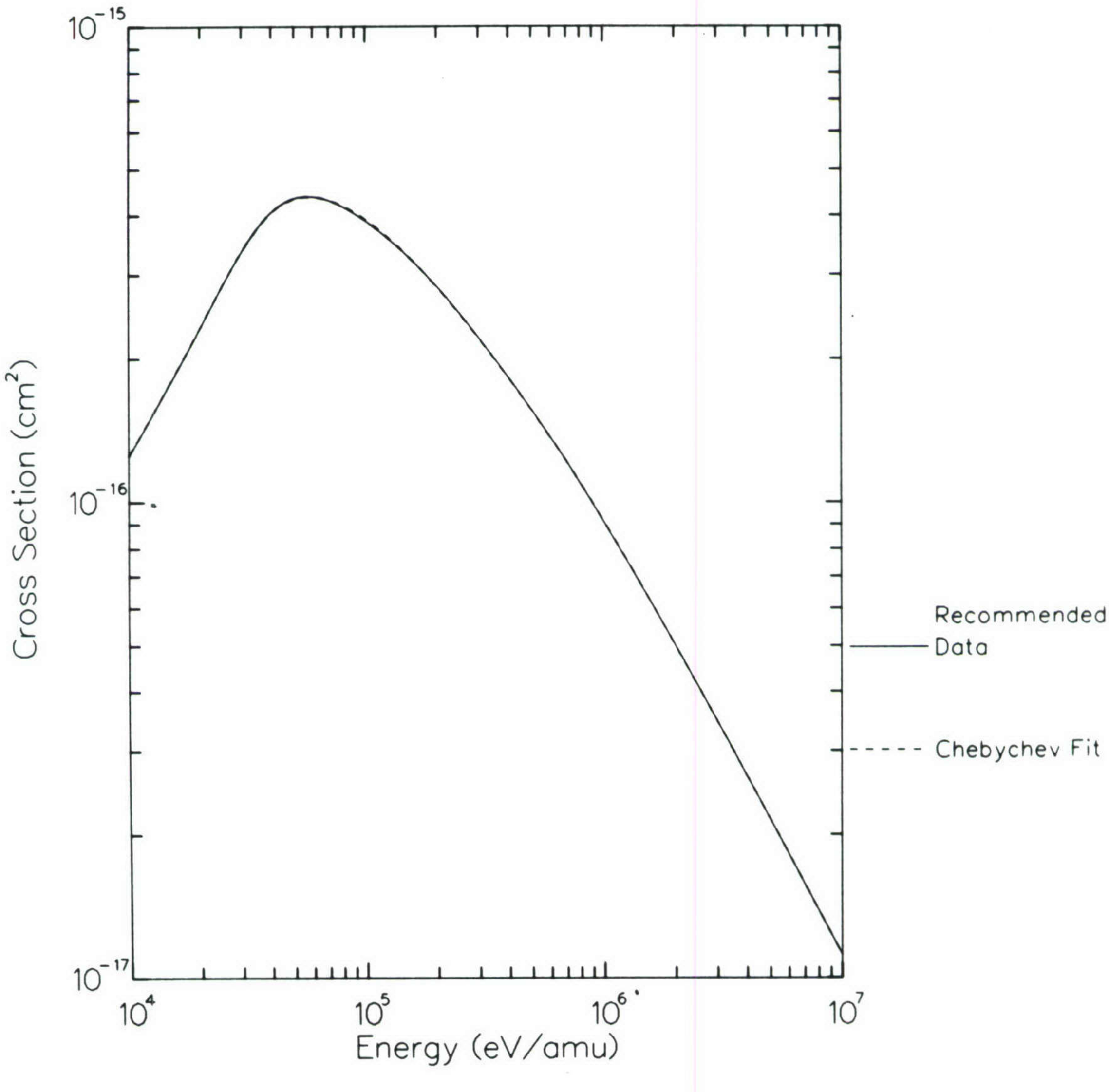
Chebychev Fitting Parameters for Cross Sections

C1	C2	C3	C4	C5	C6	C7	C8	C9
3.133E-16	-1.205E-16	-1.024E-16	1.079E-16	-2.018E-17	-2.896E-17	3.009E-17	-1.538E-17	3.994E-18

The fit represents the above cross sections with an rms deviation of 0.5%.
The maximum deviation is 1.1% at 1.0E+05 eV/amu.
See appendix for Chebychev fit details.

$O^{2+} + H \rightarrow O^{2+} + H^{+} + e^{-}$

Cross Section vs. Energy



Ionization Rate Coefficients for
$H + O^{2+} \to O^{2+} + H^{+} + e^{-}$

Beam - Maxwellian Rate Coefficients (cm^3/s)

O^{2+} Temp. (eV)	H Energy (eV/amu) 10000.	20000.	40000.	70000.	100000.	200000.	500000.
1.0E+00	8.73E-09**	4.46E-08	1.15E-07	1.57E-07	1.70E-07	1.76E-07	1.53E-07
2.0E+00	8.75E-09*	4.46E-08	1.15E-07	1.57E-07	1.70E-07	1.76E-07	1.53E-07
4.0E+00	8.77E-09*	4.46E-08	1.15E-07	1.57E-07	1.70E-07	1.76E-07	1.53E-07
7.0E+00	8.80E-09*	4.46E-08	1.15E-07	1.57E-07	1.70E-07	1.76E-07	1.53E-07
1.0E+01	8.83E-09*	4.46E-08	1.15E-07	1.57E-07	1.70E-07	1.76E-07	1.53E-07
2.0E+01	8.89E-09*	4.46E-08	1.15E-07	1.57E-07	1.70E-07	1.76E-07	1.53E-07
4.0E+01	8.98E-09*	4.46E-08	1.15E-07	1.57E-07	1.70E-07	1.76E-07	1.53E-07
7.0E+01	9.07E-09*	4.46E-08	1.15E-07	1.57E-07	1.70E-07	1.76E-07	1.53E-07
1.0E+02	9.15E-09*	4.46E-08	1.15E-07	1.57E-07	1.70E-07	1.76E-07	1.53E-07
2.0E+02	9.35E-09*	4.47E-08	1.15E-07	1.57E-07	1.70E-07	1.76E-07	1.53E-07
4.0E+02	9.65E-09*	4.47E-08	1.14E-07	1.57E-07	1.70E-07	1.76E-07	1.53E-07
7.0E+02	9.99E-09*	4.48E-08	1.14E-07	1.57E-07	1.70E-07	1.76E-07	1.53E-07
1.0E+03	1.03E-08*	4.49E-08	1.14E-07	1.57E-07	1.70E-07	1.76E-07	1.53E-07
2.0E+03	1.10E-08*	4.53E-08	1.14E-07	1.57E-07	1.70E-07	1.76E-07	1.53E-07
4.0E+03	1.22E-08*	4.60E-08	1.13E-07	1.57E-07	1.70E-07	1.76E-07	1.53E-07
7.0E+03	1.36E-08*	4.71E-08	1.13E-07	1.57E-07	1.70E-07	1.76E-07	1.53E-07
1.0E+04	1.48E-08*	4.81E-08	1.13E-07	1.57E-07	1.70E-07	1.76E-07	1.53E-07
2.0E+04	1.86E-08*	5.13E-08	1.13E-07	1.57E-07	1.70E-07	1.76E-07	1.53E-07

Accuracy: * - Possible Error Greater Than 10%
** - Possible Error Greater Than 100%

Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

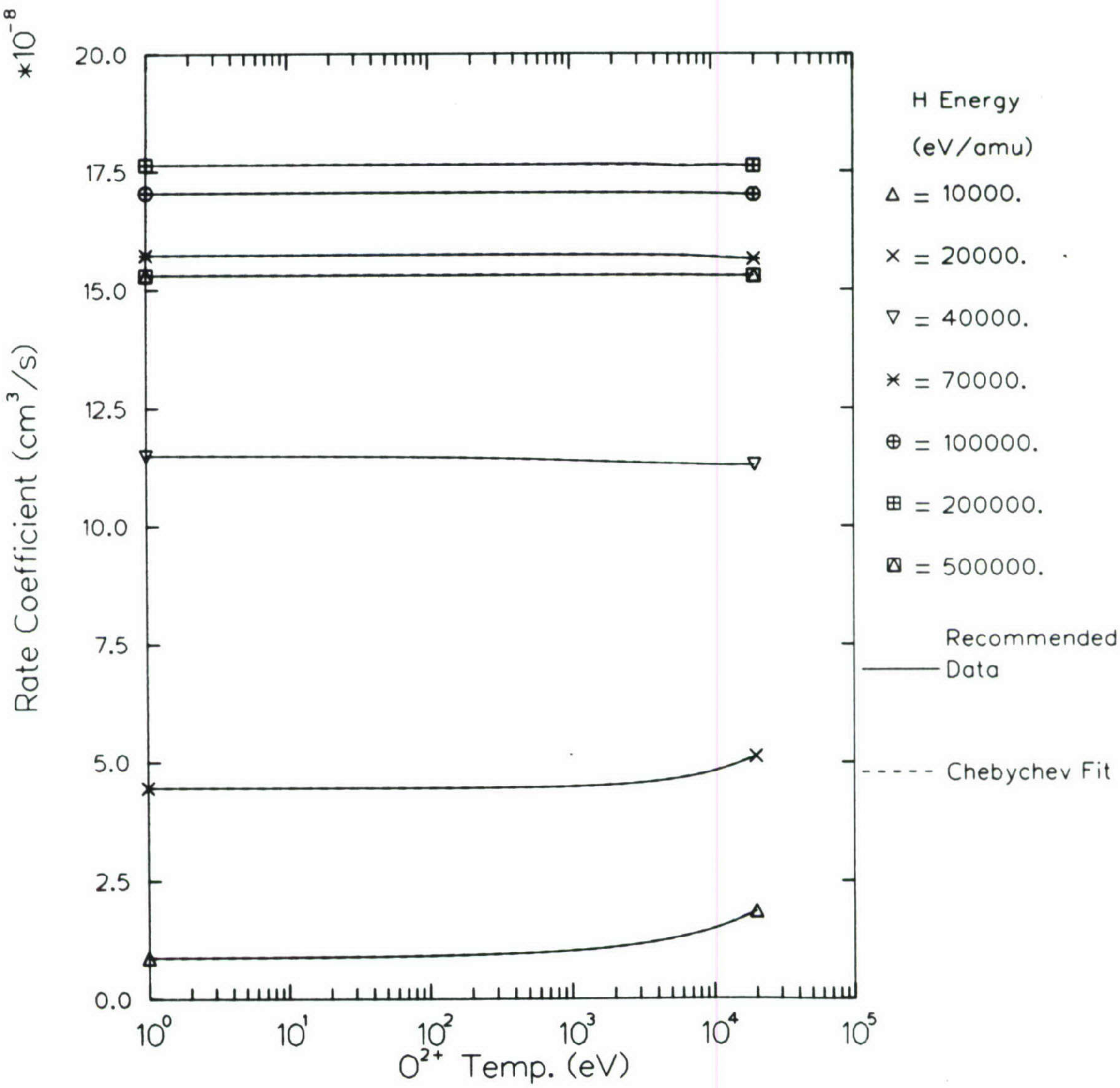
Chebychev Fitting Parameters for Rate Coefficients

H Energy (eV/amu)	C1	C2	C3	C4	C5	C6	C7
10000.	2.208E-08	3.765E-09	2.147E-09	9.886E-10	3.983E-10	1.450E-10	4.674E-11
20000.	9.171E-08	2.246E-09	1.590E-09	9.141E-10	4.290E-10	1.628E-10	4.901E-11
40000.	2.284E-07	-1.060E-09	-3.119E-10	4.200E-11	9.208E-11	5.333E-11	1.853E-11
70000.	3.144E-07	-2.277E-10	-2.204E-10	-1.506E-10	-7.343E-11	-2.507E-11	-2.111E-12
100000.	3.408E-07	-8.268E-11	-8.974E-11	-6.784E-11	-3.739E-11	-1.563E-11	-4.689E-12
200000.	3.527E-07	-8.631E-11	-7.007E-11	-3.495E-11	-4.375E-12	1.054E-11	1.195E-11
500000.	3.060E-07	-3.349E-11	-2.453E-11	-1.097E-11	-9.764E-13	4.372E-12	8.363E-12

See appendix for Chebychev fit details.

$H + O^{2+} \rightarrow O^{2+} + H^{+} + e^{-}$

Beam – Maxwellian



Ionization Cross Sections for
$O^{3+} + H \rightarrow O^{3+} + H^+ + e^-$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
1.3E+04	1.58E+08	1.34E-16
2.0E+04	1.96E+08	2.03E-16
4.0E+04	2.78E+08	4.64E-16
7.0E+04	3.68E+08	7.05E-16
1.0E+05	4.39E+08	7.00E-16
2.0E+05	6.21E+08	5.13E-16
4.0E+05	8.78E+08	3.36E-16
7.0E+05	1.16E+09	2.24E-16
1.0E+06	1.39E+09	1.68E-16
2.0E+06	1.96E+09	9.22E-17
4.0E+06	2.77E+09	5.11E-17
7.0E+06	3.65E+09	3.22E-17
1.0E+07	4.36E+09	2.30E-17

References: F.65, E.66, T.8, T.9, T.51, T.52

Accuracy: 15% for $E \leq 3x10^5$ eV/amu; 30% for $E > 3x10^5$ eV/amu

Notes: (1) In the region $E \leq 3x10^5$ eV/amu, the recommended cross section represents the experimental data, [E.65], [E.66]. At higher energies, the cross section is given by the semi-empirical scaling [T.51], (see also sect. 2.1.1).
(2) For the energy region below $3x10^5$ eV/amu the experimental cross section agrees also with the theoretical calculations of Ref. [T.52] within the indicated uncertainty.

For Chebychev fits of the above cross sections it is necessary to use the following parameters.
E_{min} = 1.3E+04 eV/amu, E_{max} = 1.0E+07 eV/amu

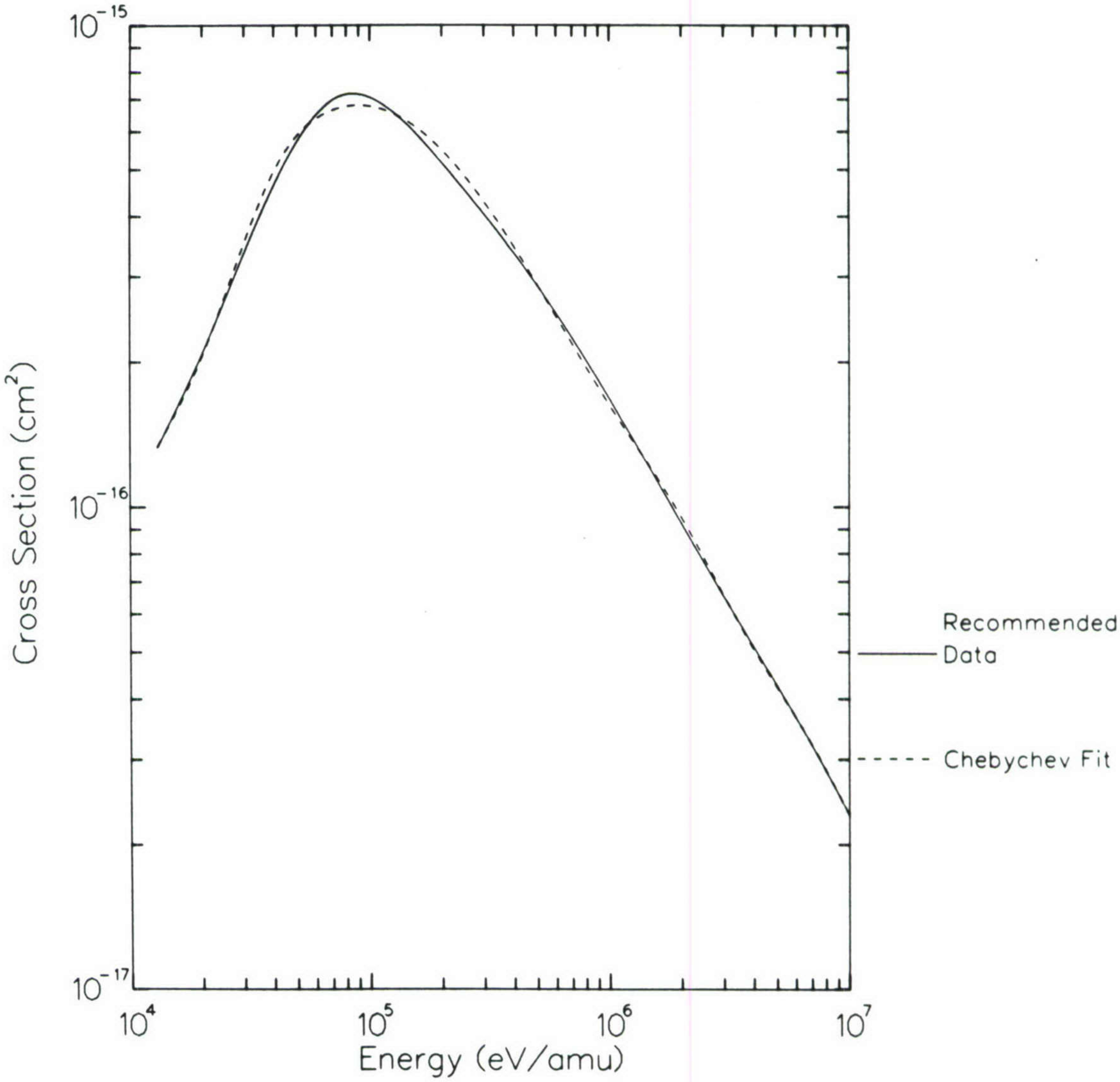
Chebychev Fitting Parameters for Cross Sections

C1	C2	C3	C4	C5	C6	C7	C8	C9
4.840E-16	-1.612E-16	-1.857E-16	1.679E-16	-8.810E-18	-6.027E-17	3.709E-17	-2.167E-18	-5.908E-18

The fit represents the above cross sections with an rms deviation of 4.3%.
The maximum deviation is 8.2% at 4.0E+04 eV/amu.
See appendix for Chebychev fit details.

$O^{3+} + H \rightarrow O^{3+} + H^{+} + e^{-}$

Cross Section vs. Energy



Ionization Rate Coefficients for
$H + O^{3+} \rightarrow O^{3+} + H^{+} + e^{-}$

Beam - Maxwellian Rate Coefficients (cm^3/s)

O^{3+} Temp. (eV)	H Energy (eV/amu) 13000.	20000.	40000.	70000.	100000.	200000.	500000.
1.0E+00	1.07E-08**	3.99E-08	1.29E-07	2.59E-07	3.07E-07	3.19E-07	2.83E-07
2.0E+00	1.07E-08**	3.99E-08	1.29E-07	2.59E-07	3.08E-07	3.19E-07	2.83E-07
4.0E+00	1.07E-08*	3.99E-08	1.29E-07	2.59E-07	3.08E-07	3.19E-07	2.83E-07
7.0E+00	1.07E-08*	3.99E-08	1.29E-07	2.59E-07	3.08E-07	3.19E-07	2.83E-07
1.0E+01	1.08E-08*	3.99E-08	1.29E-07	2.59E-07	3.08E-07	3.19E-07	2.83E-07
2.0E+01	1.08E-08*	3.99E-08	1.29E-07	2.59E-07	3.08E-07	3.19E-07	2.83E-07
4.0E+01	1.09E-08*	3.99E-08	1.29E-07	2.59E-07	3.08E-07	3.19E-07	2.83E-07
7.0E+01	1.10E-08*	3.99E-08	1.29E-07	2.59E-07	3.08E-07	3.19E-07	2.83E-07
1.0E+02	1.11E-08*	3.99E-08	1.29E-07	2.59E-07	3.08E-07	3.19E-07	2.83E-07
2.0E+02	1.13E-08*	4.00E-08	1.29E-07	2.59E-07	3.08E-07	3.19E-07	2.83E-07
4.0E+02	1.17E-08*	4.01E-08	1.28E-07	2.58E-07	3.08E-07	3.19E-07	2.83E-07
7.0E+02	1.20E-08*	4.02E-08	1.28E-07	2.58E-07	3.08E-07	3.19E-07	2.83E-07
1.0E+03	1.23E-08*	4.03E-08	1.28E-07	2.58E-07	3.08E-07	3.19E-07	2.83E-07
2.0E+03	1.32E-08*	4.08E-08	1.29E-07	2.58E-07	3.08E-07	3.19E-07	2.83E-07
4.0E+03	1.44E-08*	4.16E-08	1.29E-07	2.57E-07	3.08E-07	3.19E-07	2.83E-07
7.0E+03	1.60E-08*	4.26E-08	1.30E-07	2.56E-07	3.08E-07	3.19E-07	2.83E-07
1.0E+04	1.75E-08*	4.37E-08	1.31E-07	2.55E-07	3.07E-07	3.19E-07	2.82E-07
2.0E+04	2.18E-08*	4.76E-08	1.35E-07	2.54E-07	3.06E-07	3.19E-07	2.82E-07

Accuracy: * - Possible Error Greater Than 10%
** - Possible Error Greater Than 100%

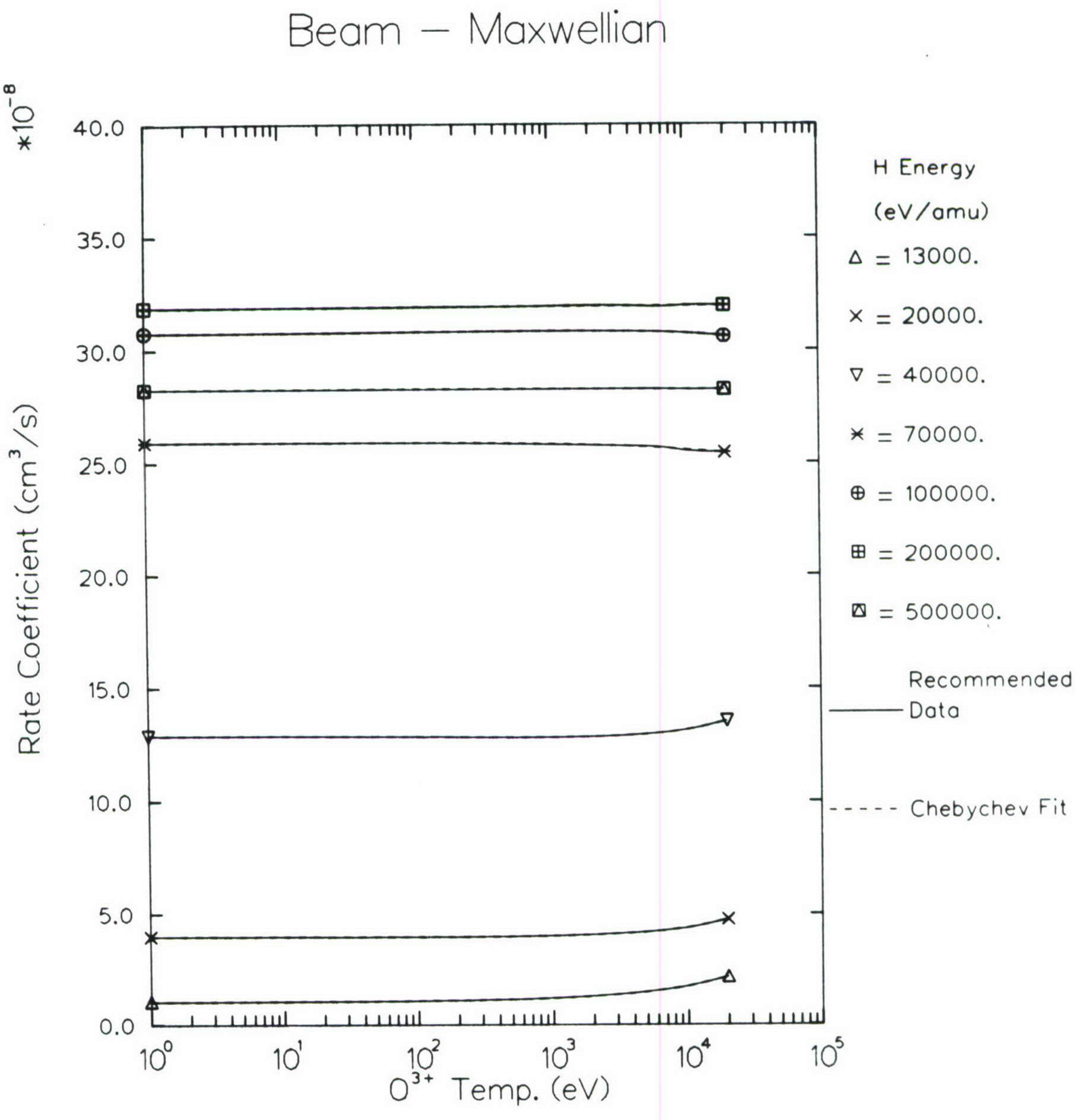
Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

Chebychev Fitting Parameters for Rate Coefficients

H Energy (eV/amu)	C1	C2	C3	C4	C5	C6	C7
13000.	2.648E-08	4.219E-09	2.438E-09	1.151E-09	4.817E-10	1.839E-10	6.306E-11
20000.	8.264E-08	2.570E-09	1.804E-09	1.045E-09	5.115E-10	2.217E-10	1.020E-10
40000.	2.595E-07	1.855E-09	1.711E-09	1.178E-09	6.117E-10	2.447E-10	7.562E-11
70000.	5.156E-07	-1.959E-09	-1.042E-09	-4.090E-10	-1.160E-10	1.119E-13	6.309E-11
100000.	6.149E-07	-2.820E-10	-4.618E-10	-4.041E-10	-2.388E-10	-1.052E-10	-3.595E-11
200000.	6.378E-07	3.548E-10	1.145E-10	1.358E-11	7.564E-12	1.982E-11	2.071E-11
500000.	5.651E-07	-7.738E-11	-5.642E-11	-2.685E-11	-5.080E-12	6.697E-12	1.492E-11

See appendix for Chebychev fit details.

$H + O^{3+} \rightarrow O^{3+} + H^{+} + e^{-}$



Ionization Cross Sections for
$O^{4+} + H \rightarrow O^{4+} + H^{+} + e^{-}$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
2.0E+04	1.96E+08	2.15E-16
4.0E+04	2.78E+08	4.98E-16
7.0E+04	3.68E+08	9.02E-16
1.0E+05	4.39E+08	1.00E-15
2.0E+05	6.21E+08	8.03E-16
4.0E+05	8.78E+08	5.48E-16
7.0E+05	1.16E+09	3.72E-16
1.0E+06	1.39E+09	2.85E-16
2.0E+06	1.96E+09	1.57E-16
4.0E+06	2.77E+09	8.64E-17
7.0E+06	3.65E+09	5.43E-17
1.0E+07	4.36E+09	4.12E-17

References: E.65, E.66, T.8, T.9, T.51, T.52

Accuracy: 15% for $E \leq 4 \times 10^5$ eV/amu; 30% for $E > 4 \times 10^5$ eV/amu

Note: In the region $E \leq 4 \times 10^5$ eV/amu, the recommended cross section represents the experimental data [E.65], [E.66] and the calculations of Ref. [T.52], which coincide down to $E = 3 \times 10^4$ eV/amu (the last experimental point). In the region above 4×10^5 eV/amu, the cross section is given by the semi-empirical formula [T.51], the results of which also coincide with the experimental data down to 4×10^4 eV/amu, (see also sect. 2.1.1).

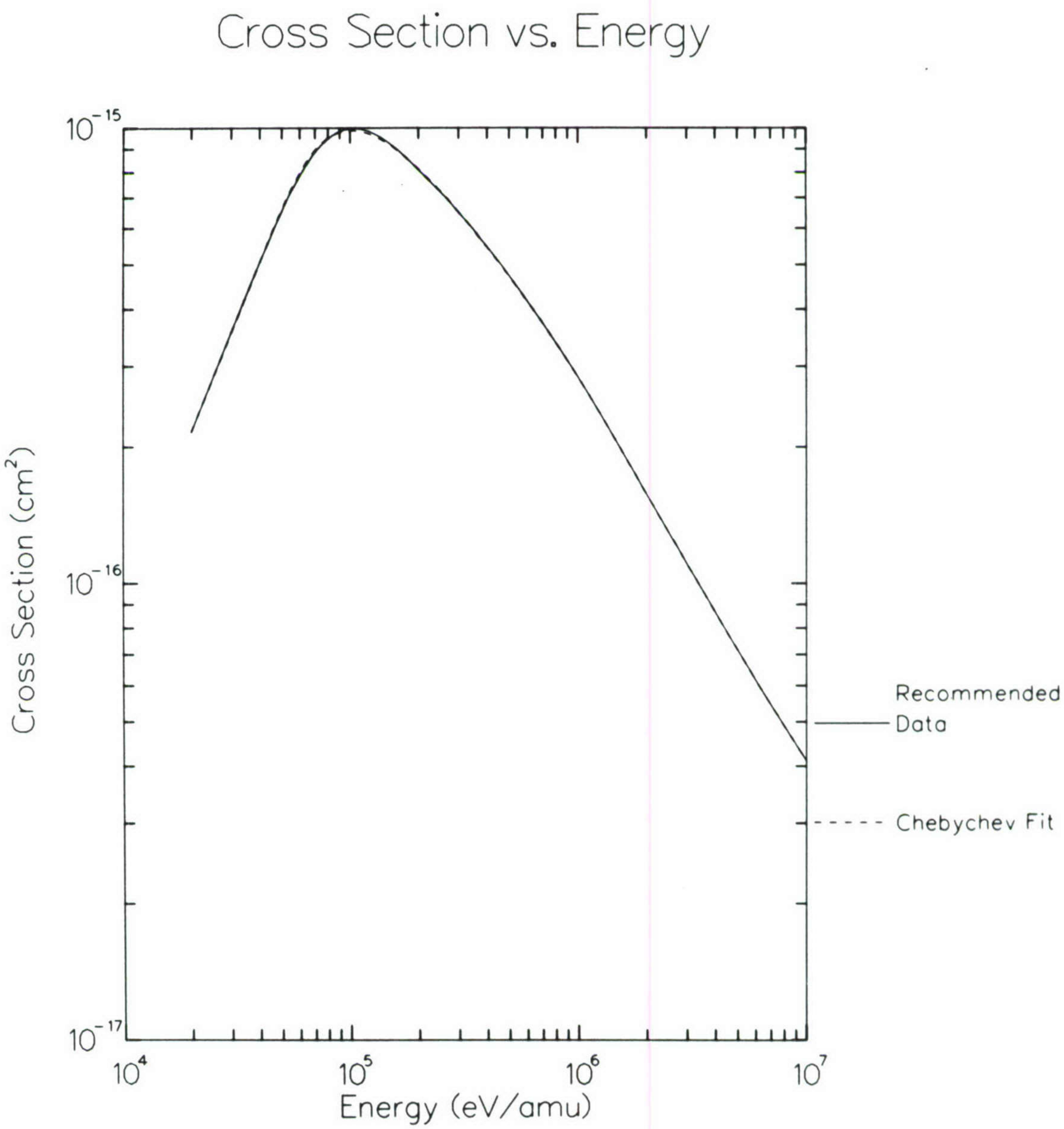
For Chebychev fits of the above cross sections it is necessary to use the following parameters.
E_{min} = 2.0E+04 eV/amu, E_{max} = 1.0E+07 eV/amu

Chebychev Fitting Parameters for Cross Sections

C1	C2	C3	C4	C5	C6	C7	C8	C9
6.849E-16	-2.180E-16	-2.662E-16	2.479E-16	-3.733E-17	-7.465E-17	7.662E-17	-4.214E-17	1.261E-17

The fit represents the above cross sections with an rms deviation of 0.7%.
The maximum deviation is 1.3% at 7.0E+04 eV/amu.
See appendix for Chebychev fit details.

$O^{4+} + H \rightarrow O^{4+} + H^{+} + e^{-}$



Ionization Rate Coefficients for
$H + O^{4+} \rightarrow O^{4+} + H^{+} + e^{-}$

Beam - Maxwellian Rate Coefficients (cm^3/s)

O^{4+} Temp. (eV)	H Energy (eV/amu) 20000.	40000.	70000.	100000.	200000.	400000.	500000.
1.0E+00	2.12E-08**	1.38E-07	3.31E-07	4.39E-07	4.99E-07	4.81E-07	4.65E-07
2.0E+00	2.13E-08**	1.38E-07	3.31E-07	4.39E-07	4.99E-07	4.81E-07	4.65E-07
4.0E+00	2.13E-08*	1.38E-07	3.31E-07	4.39E-07	4.99E-07	4.81E-07	4.65E-07
7.0E+00	2.14E-08*	1.38E-07	3.31E-07	4.39E-07	4.99E-07	4.81E-07	4.65E-07
1.0E+01	2.14E-08*	1.38E-07	3.31E-07	4.39E-07	4.99E-07	4.81E-07	4.65E-07
2.0E+01	2.16E-08*	1.38E-07	3.31E-07	4.39E-07	4.99E-07	4.81E-07	4.65E-07
4.0E+01	2.17E-08*	1.38E-07	3.31E-07	4.39E-07	4.99E-07	4.81E-07	4.65E-07
7.0E+01	2.19E-08*	1.38E-07	3.31E-07	4.39E-07	4.99E-07	4.81E-07	4.65E-07
1.0E+02	2.21E-08*	1.38E-07	3.31E-07	4.39E-07	4.99E-07	4.81E-07	4.65E-07
2.0E+02	2.25E-08*	1.38E-07	3.31E-07	4.39E-07	4.99E-07	4.81E-07	4.65E-07
4.0E+02	2.32E-08*	1.39E-07	3.30E-07	4.40E-07	5.00E-07	4.81E-07	4.65E-07
7.0E+02	2.39E-08*	1.39E-07	3.30E-07	4.40E-07	5.00E-07	4.81E-07	4.65E-07
1.0E+03	2.44E-08*	1.39E-07	3.30E-07	4.40E-07	5.00E-07	4.81E-07	4.65E-07
2.0E+03	2.60E-08*	1.40E-07	3.29E-07	4.40E-07	5.01E-07	4.81E-07	4.65E-07
4.0E+03	2.83E-08*	1.41E-07	3.28E-07	4.39E-07	5.01E-07	4.81E-07	4.65E-07
7.0E+03	3.12E-08*	1.43E-07	3.28E-07	4.39E-07	5.01E-07	4.81E-07	4.65E-07
1.0E+04	3.37E-08*	1.45E-07	3.27E-07	4.39E-07	5.02E-07	4.81E-07	4.65E-07
2.0E+04	4.10E-08*	1.52E-07	3.28E-07	4.37E-07	5.03E-07	4.81E-07	4.65E-07

Accuracy: * - Possible Error Greater Than 10%
** - Possible Error Greater Than 100%

Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

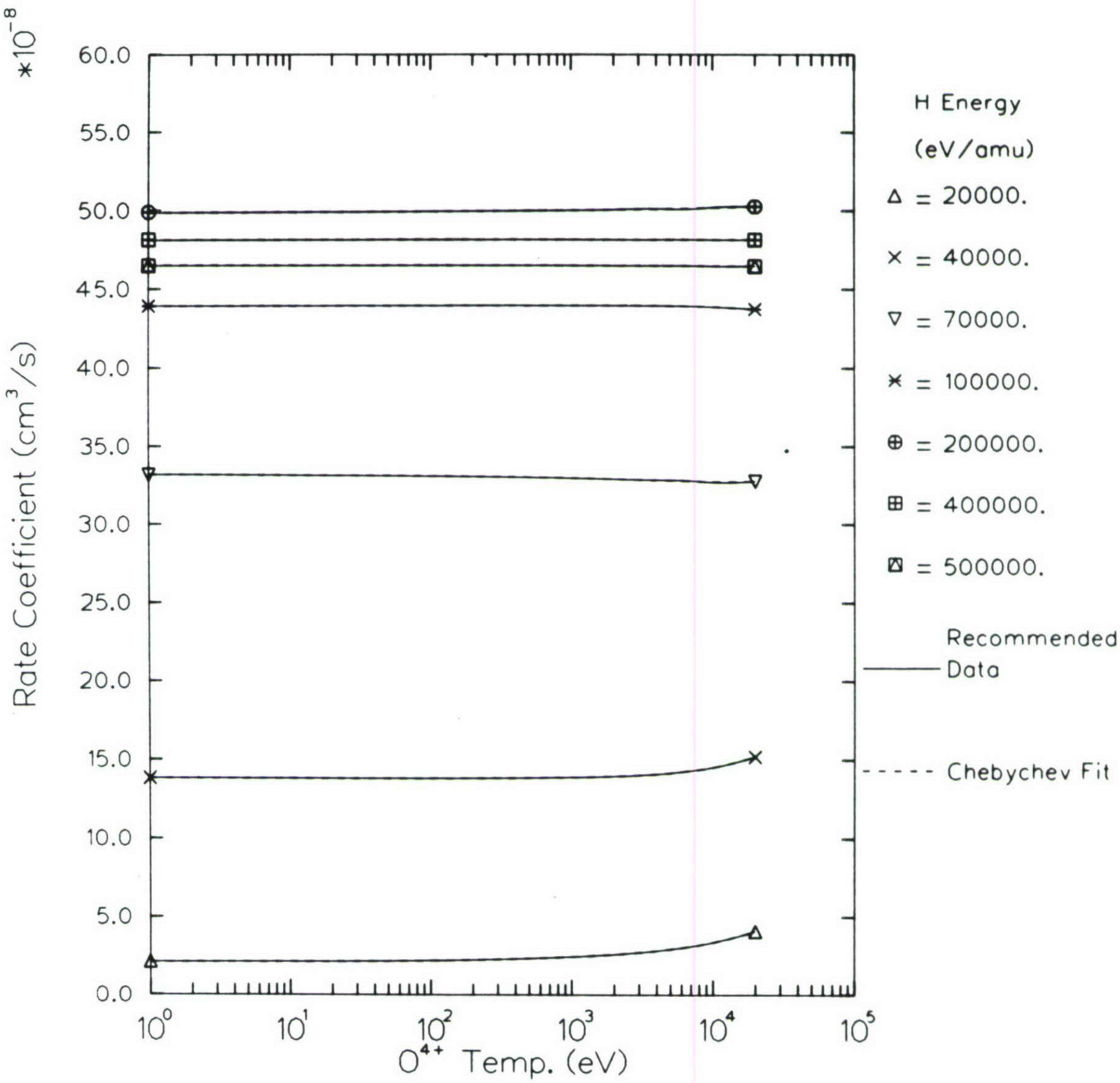
Chebychev Fitting Parameters for Rate Coefficients

H Energy (eV/amu)	C1	C2	C3	C4	C5	C6	C7
20000.	5.187E-08	7.647E-09	4.299E-09	1.933E-09	7.555E-10	2.664E-10	8.391E-11
40000.	2.818E-07	4.552E-09	3.245E-09	1.898E-09	9.173E-10	3.658E-10	1.206E-10
70000.	6.598E-07	-2.149E-09	-7.084E-10	3.353E-11	1.846E-10	1.478E-10	1.274E-10
100000.	8.782E-07	-4.206E-10	-5.238E-10	-4.215E-10	-2.415E-10	-1.056E-10	-3.674E-11
200000.	1.000E-06	1.717E-09	6.915E-10	1.556E-10	2.117E-11	2.093E-11	2.609E-11
400000.	9.627E-07	6.713E-11	-4.652E-12	-2.671E-11	-1.756E-11	-4.471E-12	5.530E-12
500000.	9.298E-07	-1.426E-10	-1.037E-10	-5.053E-11	-1.139E-11	9.859E-12	2.426E-11

See appendix for Chebychev fit details.

$H + O^{4+} \rightarrow O^{4+} + H^{+} + e^{-}$

Beam – Maxwellian



Ionization Cross Sections for
$O^{5+} + H \rightarrow O^{5+} + H^{+} + e^{-}$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
2.7E+04	2.28E+08	2.09E-16
4.0E+04	2.78E+08	3.84E-16
7.0E+04	3.68E+08	9.96E-16
1.0E+05	4.39E+08	1.30E-15
2.0E+05	6.21E+08	1.19E-15
4.0E+05	8.78E+08	8.01E-16
7.0E+05	1.16E+09	5.61E-16
1.0E+06	1.39E+09	4.32E-16
2.0E+06	1.96E+09	2.53E-16
4.0E+06	2.77E+09	1.42E-16
7.0E+06	3.65E+09	8.83E-17
1.0E+07	4.36E+09	6.47E-17

References: E.65, E.66, T.8, T.9, T.51, T.52

Accuracy: 25% for $E \leq 7x10^4$ eV/amu; 15% for $7x10^4 <$ E(eV/amu) $< 5x10^5$; 30% for $E \geq 5x10^5$ eV/amu

Note: The recommended cross section in the region below $E = 5x10^5$ eV/amu is based on the experimental data [E.65], [E.66], the calculations in Ref. [T.52] and the semi-empirical scaling formula [T.51], which all agree within the indicated uncertainty. For $E > 5x10^5$ eV/amu the cross section is given by the semi-empirical formula [T.51], (see also sect. 2.1.1).

For Chebychev fits of the above cross sections it is necessary to use the following parameters.
E_{min} = 2.7E+04 eV/amu, E_{max} = 1.0E+07 eV/amu

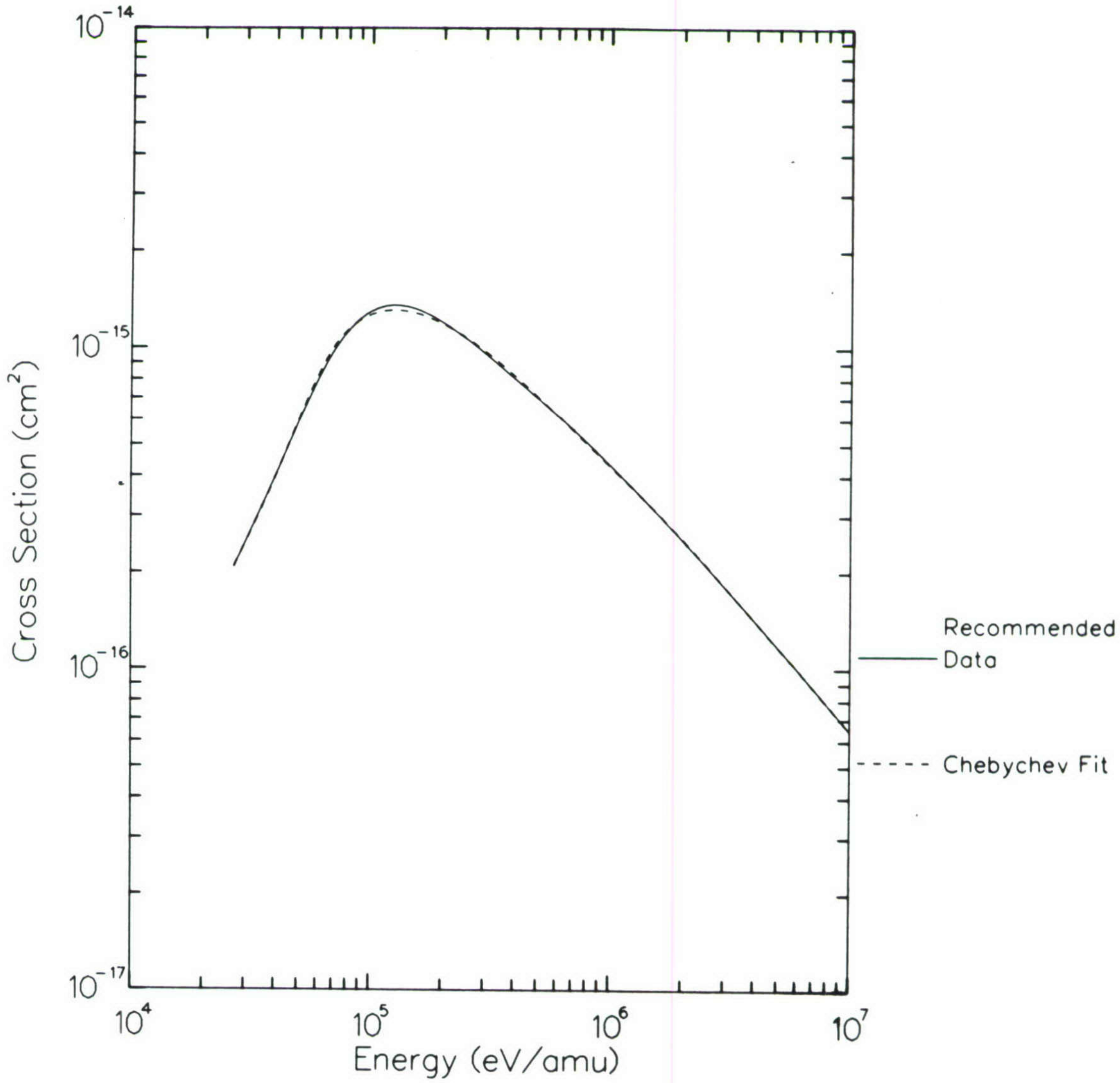
Chebychev Fitting Parameters for Cross Sections

C1	C2	C3	C4	C5	C6	C7	C8	C9
9.399E-16	-2.858E-16	-3.570E-16	3.292E-16	-6.377E-17	-7.973E-17	8.204E-17	-3.596E-17	5.633E-18

The fit represents the above cross sections with an rms deviation of 1.6%.
The maximum deviation is 3.2% at 7.0E+04 eV/amu.
See appendix for Chebychev fit details.

$O^{5+} + H \rightarrow O^{5+} + H^{+} + e^{-}$

Cross Section vs. Energy



Ionization Rate Coefficients for
$H + O^{5+} \rightarrow O^{5+} + H^{+} + e^{-}$

Beam - Maxwellian Rate Coefficients (cm^3/s)

O^{5+} Temp. (eV)	H Energy (eV/amu) 20000.	40000.	70000.	100000.	200000.	400000.	500000.
1.0E+00	1.17E-08**	1.07E-07	3.66E-07	5.71E-07	7.39E-07	7.04E-07	6.85E-07
2.0E+00	1.17E-08**	1.07E-07	3.66E-07	5.71E-07	7.39E-07	7.04E-07	6.85E-07
4.0E+00	1.17E-08*	1.07E-07	3.66E-07	5.71E-07	7.39E-07	7.04E-07	6.85E-07
7.0E+00	1.18E-08*	1.07E-07	3.66E-07	5.71E-07	7.39E-07	7.04E-07	6.85E-07
1.0E+01	1.18E-08*	1.07E-07	3.66E-07	5.71E-07	7.39E-07	7.04E-07	6.85E-07
2.0E+01	1.19E-08*	1.07E-07	3.65E-07	5.71E-07	7.40E-07	7.04E-07	6.85E-07
4.0E+01	1.20E-08*	1.07E-07	3.65E-07	5.71E-07	7.40E-07	7.04E-07	6.85E-07
7.0E+01	1.22E-08*	1.07E-07	3.65E-07	5.71E-07	7.40E-07	7.04E-07	6.85E-07
1.0E+02	1.23E-08*	1.07E-07	3.65E-07	5.71E-07	7.40E-07	7.04E-07	6.85E-07
2.0E+02	1.26E-08*	1.07E-07	3.64E-07	5.71E-07	7.40E-07	7.04E-07	6.85E-07
4.0E+02	1.31E-08*	1.07E-07	3.64E-07	5.71E-07	7.41E-07	7.04E-07	6.85E-07
7.0E+02	1.36E-08*	1.08E-07	3.63E-07	5.71E-07	7.41E-07	7.04E-07	6.85E-07
1.0E+03	1.41E-08*	1.08E-07	3.63E-07	5.71E-07	7.42E-07	7.04E-07	6.85E-07
2.0E+03	1.53E-08*	1.09E-07	3.63E-07	5.71E-07	7.42E-07	7.05E-07	6.85E-07
4.0E+03	1.71E-08*	1.11E-07	3.62E-07	5.71E-07	7.43E-07	7.05E-07	6.85E-07
7.0E+03	1.94E-08*	1.14E-07	3.63E-07	5.71E-07	7.43E-07	7.06E-07	6.85E-07
1.0E+04	2.15E-08*	1.17E-07	3.63E-07	5.71E-07	7.45E-07	7.06E-07	6.85E-07
2.0E+04	2.76E-08*	1.27E-07	3.67E-07	5.70E-07	7.45E-07	7.07E-07	6.85E-07

Accuracy: * - Possible Error Greater Than 10%
** - Possible Error Greater Than 100%

Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

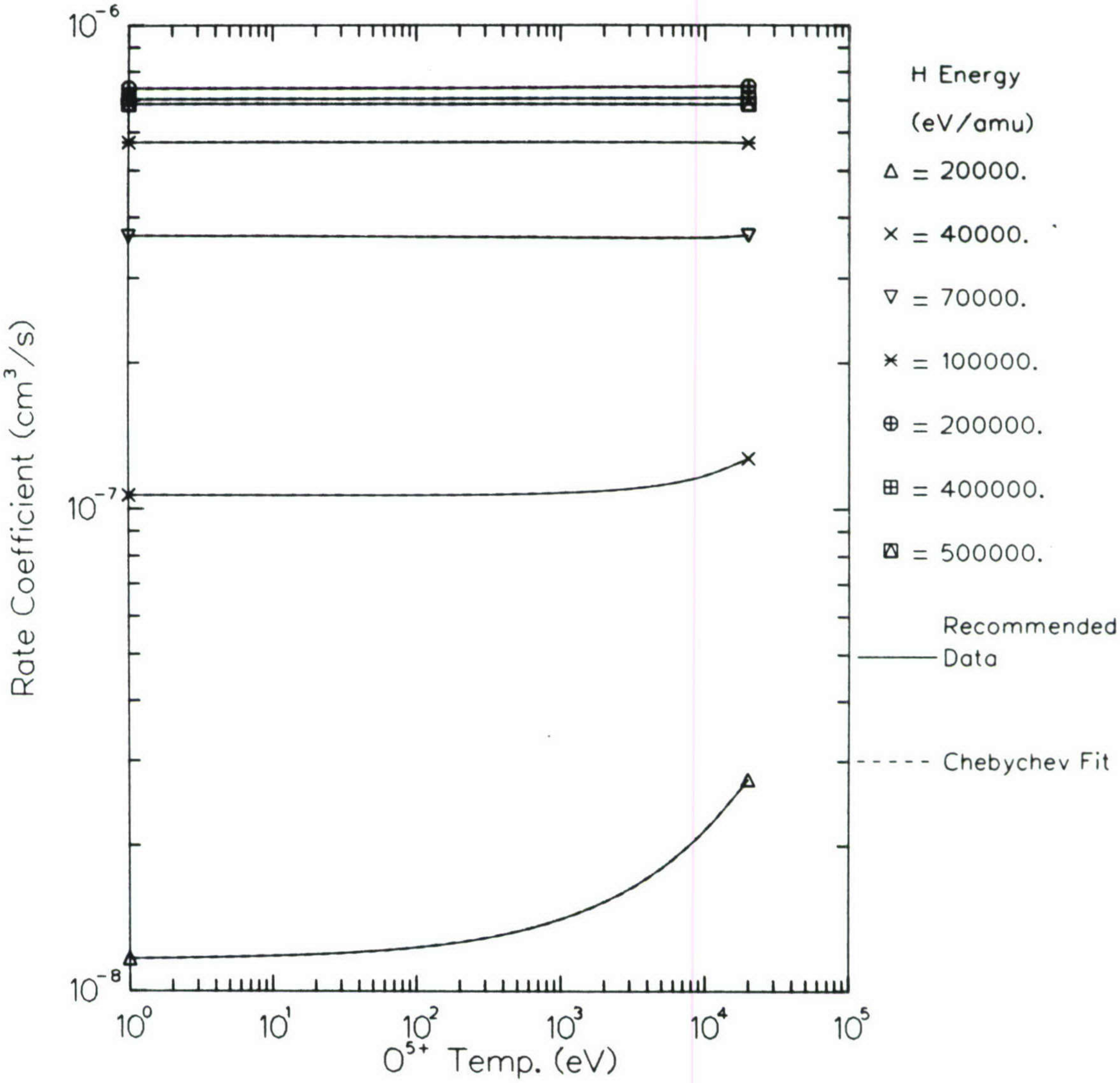
Chebychev Fitting Parameters for Rate Coefficients

H Energy (eV/amu)	C1	C2	C3	C4	C5	C6	C7
20000.	3.074E-08	6.061E-09	3.484E-09	1.620E-09	6.573E-10	2.391E-10	7.583E-11
40000.	2.213E-07	6.916E-09	4.756E-09	2.739E-09	1.346E-09	5.648E-10	2.066E-10
70000.	7.296E-07	-9.546E-10	7.880E-10	1.208E-09	8.280E-10	4.170E-10	2.307E-10
100000.	1.142E-06	-1.676E-10	-3.467E-10	-3.172E-10	-1.891E-10	-8.328E-11	-2.821E-11
200000.	1.483E-06	2.956E-09	1.108E-09	1.691E-10	-3.571E-11	-5.311E-12	2.427E-11
400000.	1.409E-06	1.372E-09	6.196E-10	1.802E-10	3.095E-11	3.839E-12	9.009E-12
500000.	1.370E-06	-1.362E-10	-9.993E-11	-4.289E-11	-9.197E-13	2.139E-11	3.859E-11

See appendix for Chebychev fit details.

$H + O^{5+} \rightarrow O^{5+} + H^{+} + e^{-}$

Beam — Maxwellian



Ionization Cross Sections for
$O^{6+} + H \rightarrow O^{6+} + H^+ + e^-$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
3.0E+04	2.37E+08	1.88E-16
4.0E+04	2.78E+08	4.42E-16
7.0E+04	3.68E+08	1.09E-15
1.0E+05	4.39E+08	1.44E-15
2.0E+05	6.21E+08	1.58E-15
4.0E+05	8.78E+08	1.19E-15
7.0E+05	1.16E+09	8.45E-16
1.0E+06	1.39E+09	6.53E-16
2.0E+06	1.96E+09	3.83E-16
4.0E+06	2.77E+09	2.06E-16
7.0E+06	3.65E+09	1.27E-16
1.0E+07	4.36E+09	9.27E-17

References: E.65, T.8, T.9, T.17, T.51

Accuracy: 30% for $E < 2x10^5$ eV/amu; 15% for $2x10^5 \leq E(eV/amu) \leq 5x10^5$; 30% for $E > 5x10^5$ eV/amu

Note: In the region $2x10^5 \leq E(eV/amu) \leq 4x10^5$ the recommended cross section is constructed on the basis of experimental data [E.65], which coincide with the results of the semi-empirical scaling formula [T.51]. This formula has been used to generate the cross section at energies below and above this region, (see also sect. 2.1.1).

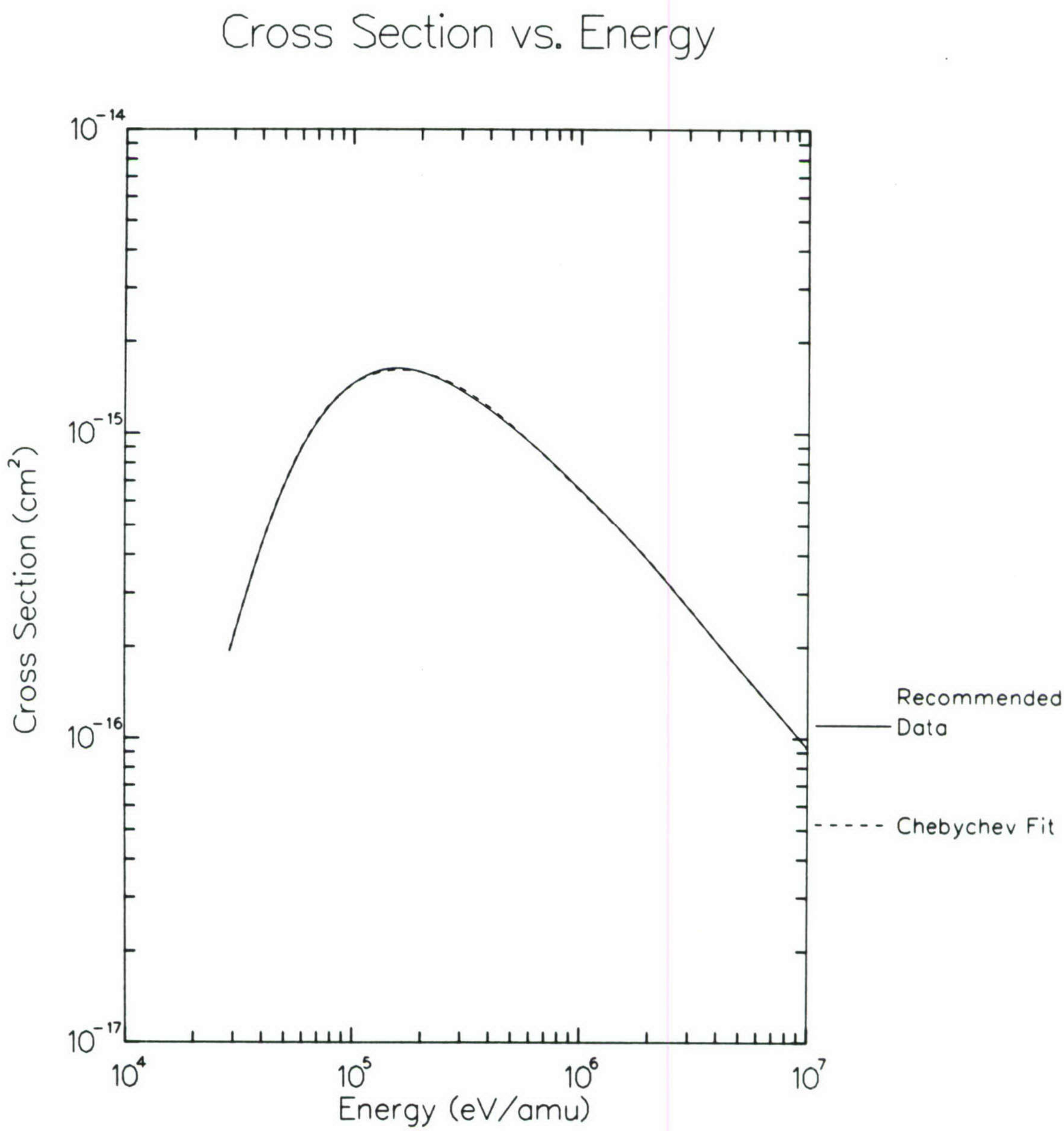
For Chebychev fits of the above cross sections it is necessary to use the following parameters.
E_{min} = 2.9E+04 eV/amu, E_{max} = 1.0E+07 eV/amu

Chebychev Fitting Parameters for Cross Sections

C1	C2	C3	C4	C5	C6	C7	C8	C9
1.233E-15	-3.306E-16	-4.988E-16	3.899E-16	-2.938E-17	-1.023E-16	6.441E-17	-4.703E-18	-1.224E-17

The fit represents the above cross sections with an rms deviation of 1.0%.
The maximum deviation is 2.1% at 4.0E+05 eV/amu.
See appendix for Chebychev fit details.

$O^{6+} + H \rightarrow O^{6+} + H^{+} + e^{-}$



Ionization Rate Coefficients for
$H + O^{6+} \rightarrow O^{6+} + H^+ + e^-$

Beam - Maxwellian Rate Coefficients (cm^3/s)

O^{6+} Temp. (eV)	H Energy (eV/amu) 20000.	40000.	70000.	100000.	200000.	400000.	500000.
1.0E+00	6.14E-09**	1.23E-07	4.01E-07	6.33E-07	9.81E-07	1.05E-06	1.03E-06
2.0E+00	6.16E-09**	1.23E-07	4.01E-07	6.33E-07	9.81E-07	1.05E-06	1.03E-06
4.0E+00	6.19E-09*	1.23E-07	4.01E-07	6.33E-07	9.81E-07	1.05E-06	1.03E-06
7.0E+00	6.23E-09*	1.23E-07	4.01E-07	6.33E-07	9.81E-07	1.05E-06	1.03E-06
1.0E+01	6.25E-09*	1.23E-07	4.01E-07	6.33E-07	9.81E-07	1.05E-06	1.03E-06
2.0E+01	6.32E-09*	1.23E-07	4.01E-07	6.33E-07	9.82E-07	1.05E-06	1.03E-06
4.0E+01	6.42E-09*	1.23E-07	4.01E-07	6.33E-07	9.82E-07	1.05E-06	1.03E-06
7.0E+01	6.53E-09*	1.23E-07	4.01E-07	6.33E-07	9.82E-07	1.05E-06	1.03E-06
1.0E+02	6.62E-09*	1.23E-07	4.01E-07	6.33E-07	9.82E-07	1.05E-06	1.03E-06
2.0E+02	6.86E-09*	1.23E-07	4.01E-07	6.33E-07	9.82E-07	1.05E-06	1.03E-06
4.0E+02	7.22E-09*	1.23E-07	4.01E-07	6.33E-07	9.82E-07	1.05E-06	1.03E-06
7.0E+02	7.64E-09*	1.23E-07	4.02E-07	6.33E-07	9.82E-07	1.05E-06	1.03E-06
1.0E+03	7.99E-09*	1.24E-07	4.02E-07	6.33E-07	9.82E-07	1.05E-06	1.03E-06
2.0E+03	8.99E-09*	1.25E-07	4.03E-07	6.34E-07	9.82E-07	1.05E-06	1.03E-06
4.0E+03	1.06E-08*	1.27E-07	4.04E-07	6.35E-07	9.82E-07	1.05E-06	1.03E-06
7.0E+03	1.29E-08*	1.31E-07	4.06E-07	6.35E-07	9.81E-07	1.05E-06	1.03E-06
1.0E+04	1.50E-08*	1.35E-07	4.08E-07	6.36E-07	9.82E-07	1.05E-06	1.03E-06
2.0E+04	2.21E-08*	1.46E-07	4.13E-07	6.35E-07	9.81E-07	1.05E-06	1.03E-06

Accuracy: * - Possible Error Greater Than 10%
 ** - Possible Error Greater Than 100%

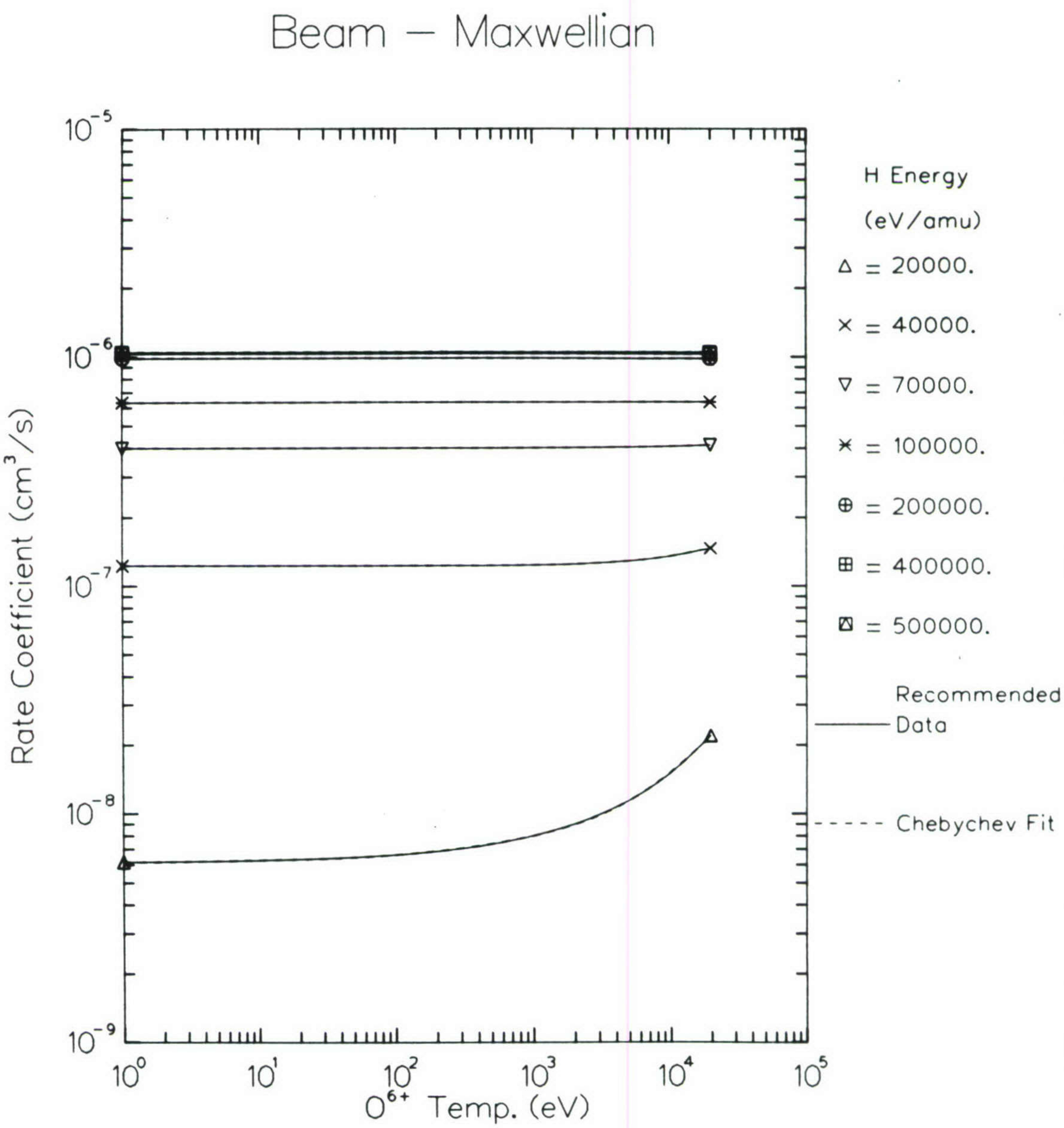
Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

Chebychev Fitting Parameters for Rate Coefficients

H Energy (eV/amu)	C1	C2	C3	C4	C5	C6	C7
20000.	1.907E-08	5.699E-09	3.538E-09	1.850E-09	8.623E-10	3.577E-10	1.239E-10
40000.	2.542E-07	7.818E-09	5.716E-09	3.361E-09	1.592E-09	6.059E-10	1.845E-10
70000.	8.066E-07	4.537E-09	2.850E-09	1.485E-09	6.703E-10	2.653E-10	9.524E-11
100000.	1.267E-06	1.524E-09	6.296E-10	4.581E-11	-1.737E-10	-1.774E-10	-1.505E-10
200000.	1.963E-06	2.139E-10	-2.155E-10	-2.556E-10	-1.047E-10	1.709E-11	5.243E-11
400000.	2.091E-06	6.207E-10	1.970E-10	-5.563E-12	-3.585E-11	-1.450E-11	9.359E-12
500000.	2.063E-06	-3.846E-10	-2.790E-10	-1.405E-10	-3.874E-11	1.684E-11	5.270E-11

See appendix for Chebychev fit details.

$H + O^{6+} \rightarrow O^{6+} + H^{+} + e^{-}$



Ionization Cross Sections for
$O^{7+} + H \rightarrow O^{7+} + H^{+} + e^{-}$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
2.9E+04	2.37E+08	1.72E-16
4.0E+04	2.78E+08	3.85E-16
7.0E+04	3.68E+08	1.08E-15
1.0E+05	4.39E+08	1.69E-15
1.5E+05	5.38E+08	2.13E-15
2.0E+05	6.21E+08	2.06E-15
4.0E+05	8.78E+08	1.55E-15
7.0E+05	1.16E+09	1.11E-15
1.0E+06	1.39E+09	8.49E-16
2.0E+06	1.96E+09	4.93E-16
4.0E+06	2.77E+09	2.79E-16
7.0E+06	3.65E+09	1.74E-16
1.0E+07	4.36E+09	1.29E-16

References: T.8, T.9, T.51

Accuracy: 40% for $E < 1\times10^5$ eV/amu; 30% for $E \geq 1\times10^5$ eV/amu

Note: No experimental data are available for this reaction. The cross section is constructed on the basis of the semi-empirical scaling formula [T.51] (see sect. 2.1.1) and the empirical scaling for E_m (the energy at which the cross section maximum appears). This has been estimated from O^{q+} + H (q = 2-5) experimental data, (see sect. 2.1.1).

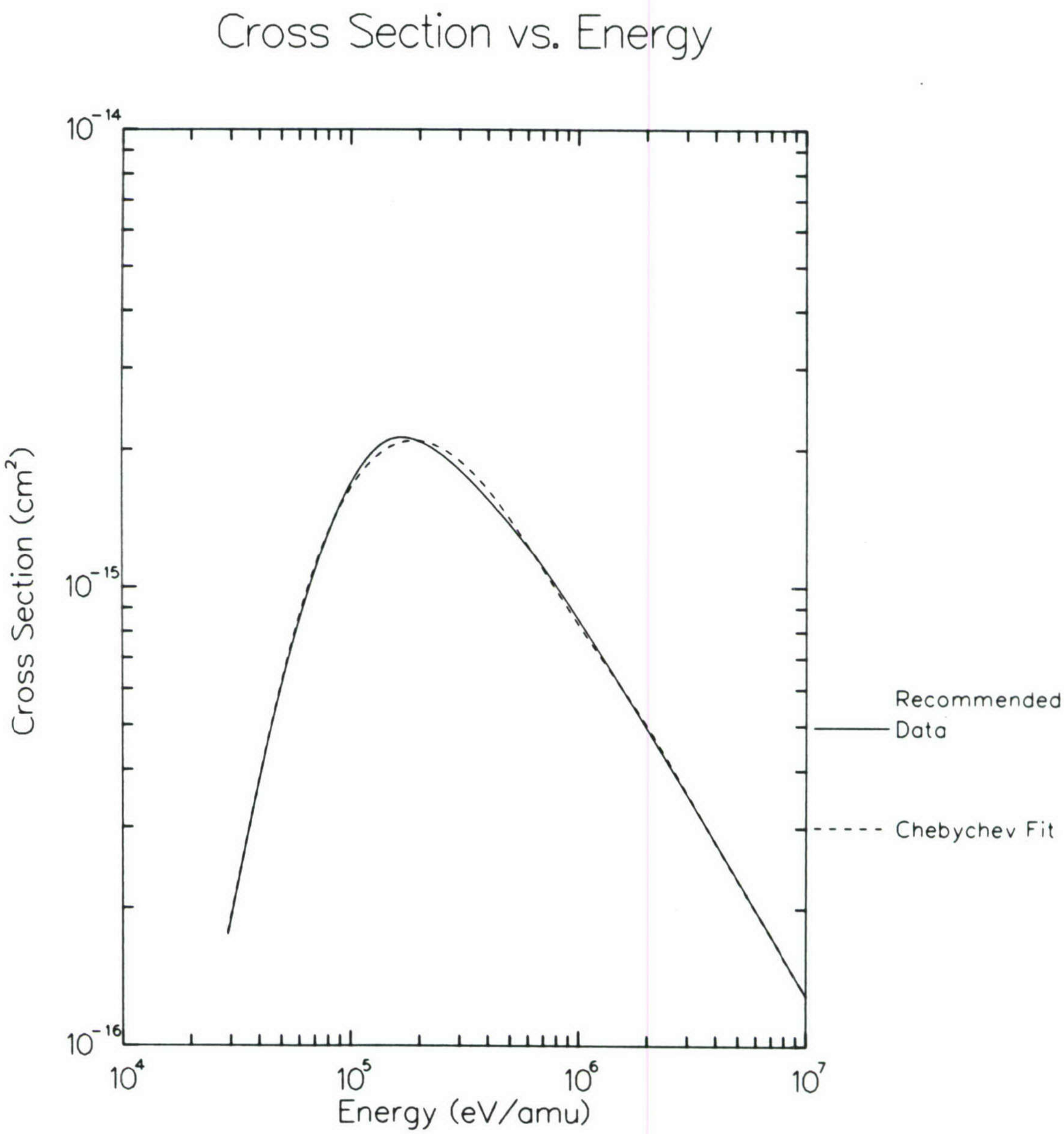
For Chebychev fits of the above cross sections it is necessary to use the following parameters.
E_{min} = 2.9E+04 eV/amu, E_{max} = 1.0E+07 eV/amu

Chebychev Fitting Parameters for Cross Sections

C1	C2	C3	C4	C5	C6	C7	C8	C9
1.488E-15	-3.257E-16	-6.832E-16	4.730E-16	3.812E-17	-1.943E-16	8.860E-17	2.543E-17	-3.675E-17

The fit represents the above cross sections with an rms deviation of 2.7%.
The maximum deviation is 5.6% at 4.0E+05 eV/amu.
See appendix for Chebychev fit details.

$O^{7+} + H \rightarrow O^{7+} + H^+ + e^-$



Ionization Rate Coefficients for
$H + O^{7+} \rightarrow O^{7+} + H^+ + e^-$

Beam - Maxwellian Rate Coefficients (cm^3/s)

O^{7+} Temp. (eV)	H Energy (eV/amu) 20000.	40000.	70000.	100000.	200000.	400000.	500000.
1.0E+00	6.06E-09**	1.07E-07	3.97E-07	7.42E-07	1.28E-06	1.36E-06	1.35E-06
2.0E+00	6.08E-09**	1.07E-07	3.97E-07	7.42E-07	1.28E-06	1.36E-06	1.35E-06
4.0E+00	6.11E-09*	1.07E-07	3.97E-07	7.42E-07	1.28E-06	1.36E-06	1.35E-06
7.0E+00	6.14E-09*	1.07E-07	3.97E-07	7.42E-07	1.28E-06	1.36E-06	1.35E-06
1.0E+01	6.16E-09*	1.07E-07	3.97E-07	7.42E-07	1.28E-06	1.36E-06	1.35E-06
2.0E+01	6.23E-09*	1.07E-07	3.97E-07	7.42E-07	1.28E-06	1.36E-06	1.35E-06
4.0E+01	6.32E-09*	1.07E-07	3.97E-07	7.42E-07	1.28E-06	1.36E-06	1.35E-06
7.0E+01	6.42E-09*	1.07E-07	3.97E-07	7.42E-07	1.28E-06	1.36E-06	1.35E-06
1.0E+02	6.51E-09*	1.07E-07	3.97E-07	7.42E-07	1.28E-06	1.36E-06	1.35E-06
2.0E+02	6.73E-09*	1.07E-07	3.97E-07	7.42E-07	1.28E-06	1.36E-06	1.35E-06
4.0E+02	7.06E-09*	1.07E-07	3.98E-07	7.42E-07	1.28E-06	1.36E-06	1.35E-06
7.0E+02	7.44E-09*	1.08E-07	3.98E-07	7.42E-07	1.28E-06	1.36E-06	1.35E-06
1.0E+03	7.77E-09*	1.08E-07	3.99E-07	7.42E-07	1.28E-06	1.36E-06	1.35E-06
2.0E+03	8.67E-09*	1.09E-07	4.00E-07	7.42E-07	1.28E-06	1.36E-06	1.35E-06
4.0E+03	1.02E-08*	1.12E-07	4.03E-07	7.43E-07	1.28E-06	1.36E-06	1.35E-06
7.0E+03	1.22E-08*	1.15E-07	4.06E-07	7.44E-07	1.28E-06	1.36E-06	1.35E-06
1.0E+04	1.40E-08*	1.19E-07	4.10E-07	7.45E-07	1.28E-06	1.36E-06	1.35E-06
2.0E+04	2.02E-08*	1.31E-07	4.23E-07	7.47E-07	1.28E-06	1.36E-06	1.35E-06

Accuracy: * - Possible Error Greater Than 10%
** - Possible Error Greater Than 100%

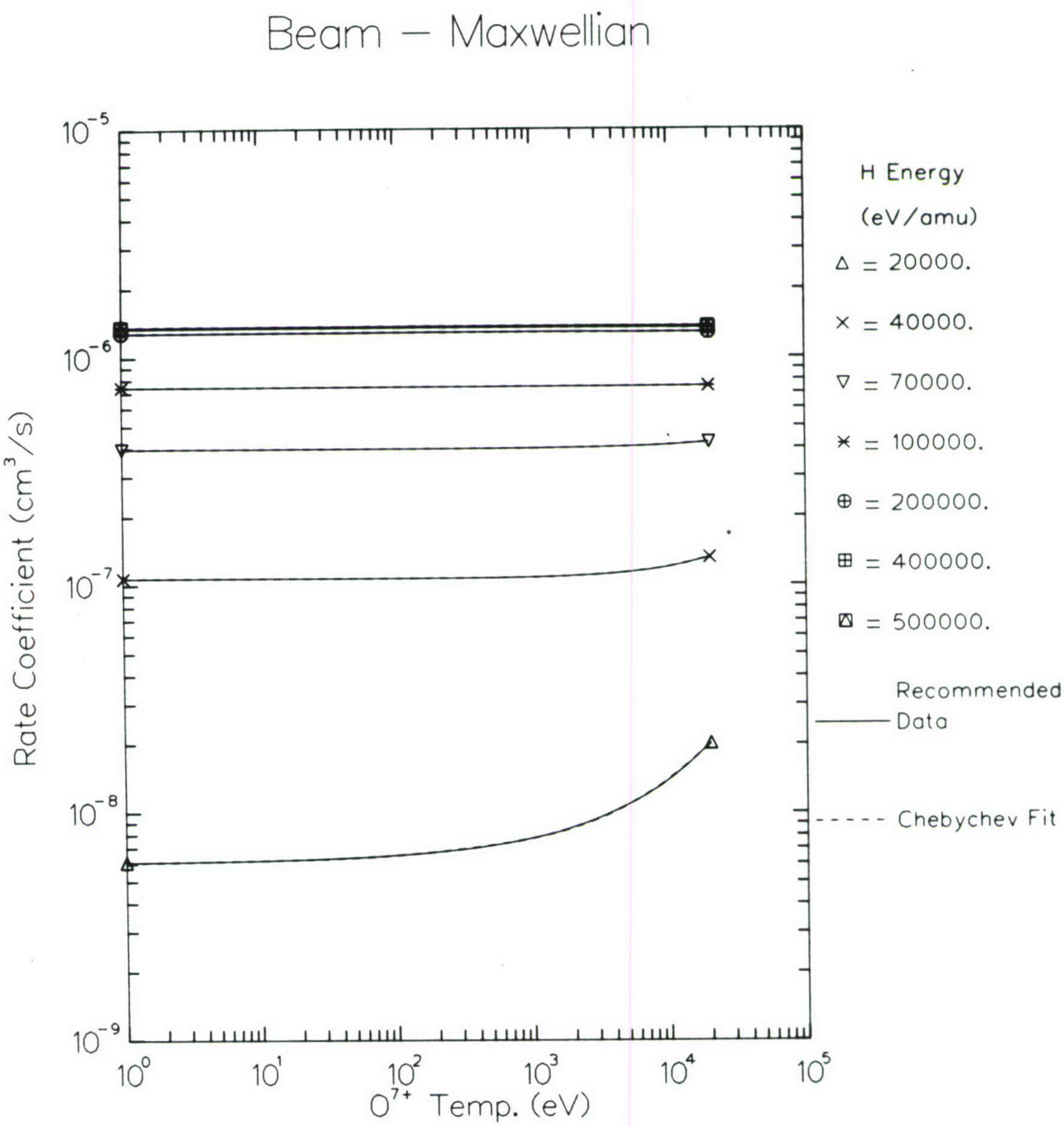
Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

Chebychev Fitting Parameters for Rate Coefficients

H Energy (eV/amu)	C1	C2	C3	C4	C5	C6	C7
20000.	1.821E-08	5.097E-09	3.133E-09	1.617E-09	7.442E-10	3.060E-10	1.062E-10
40000.	2.228E-07	8.040E-09	5.810E-09	3.429E-09	1.663E-09	6.644E-10	2.223E-10
70000.	8.037E-07	8.702E-09	6.050E-09	3.466E-09	1.657E-09	6.611E-10	2.236E-10
100000.	1.486E-06	1.513E-09	1.298E-09	7.390E-10	2.171E-10	-3.696E-11	-1.335E-10
200000.	2.562E-06	1.490E-09	1.183E-10	-3.424E-10	-2.226E-10	-3.272E-11	4.524E-11
400000.	2.724E-06	1.154E-09	4.301E-10	5.608E-11	-2.880E-11	-1.484E-11	1.294E-11
500000.	2.694E-06	-4.678E-10	-3.397E-10	-1.688E-10	-4.324E-11	2.515E-11	7.013E-11

See appendix for Chebychev fit details.

$H + O^{7+} \rightarrow O^{7+} + H^{+} + e^{-}$



Ionization Cross Sections for
$O^{8+} + H \rightarrow O^{8+} + H^{+} + e^{-}$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
2.7E+04	2.28E+08	1.94E-16
4.0E+04	2.78E+08	4.62E-16
7.0E+04	3.68E+08	1.20E-15
1.0E+05	4.39E+08	1.85E-15
1.6E+05	5.56E+08	2.55E-15
2.0E+05	6.21E+08	2.52E-15
4.0E+05	8.78E+08	1.92E-15
7.0E+05	1.16E+09	1.32E-15
1.0E+06	1.39E+09	1.04E-15
2.0E+06	1.96E+09	6.18E-16
4.0E+06	2.77E+09	3.52E-16
7.0E+06	3.65E+09	2.15E-16
1.0E+07	4.36E+09	1.57E-16

References: T.8, T.9, T.23, T.37, T.51, T.53

Accuracy: 40% for $E < 1 \times 10^5$ eV/amu; 30% for $E \geq 1 \times 10^5$ eV/amu

Note: No experimental data are available for this reaction. In the region $E < 7 \times 10^4$ eV/amu the cross section is constructed on the basis of calculations of Ref. [T.23], [T.53], and above this energy, on the basis of the semi-empirical scaling formula [T.51], (see also sect. 2.1.1).

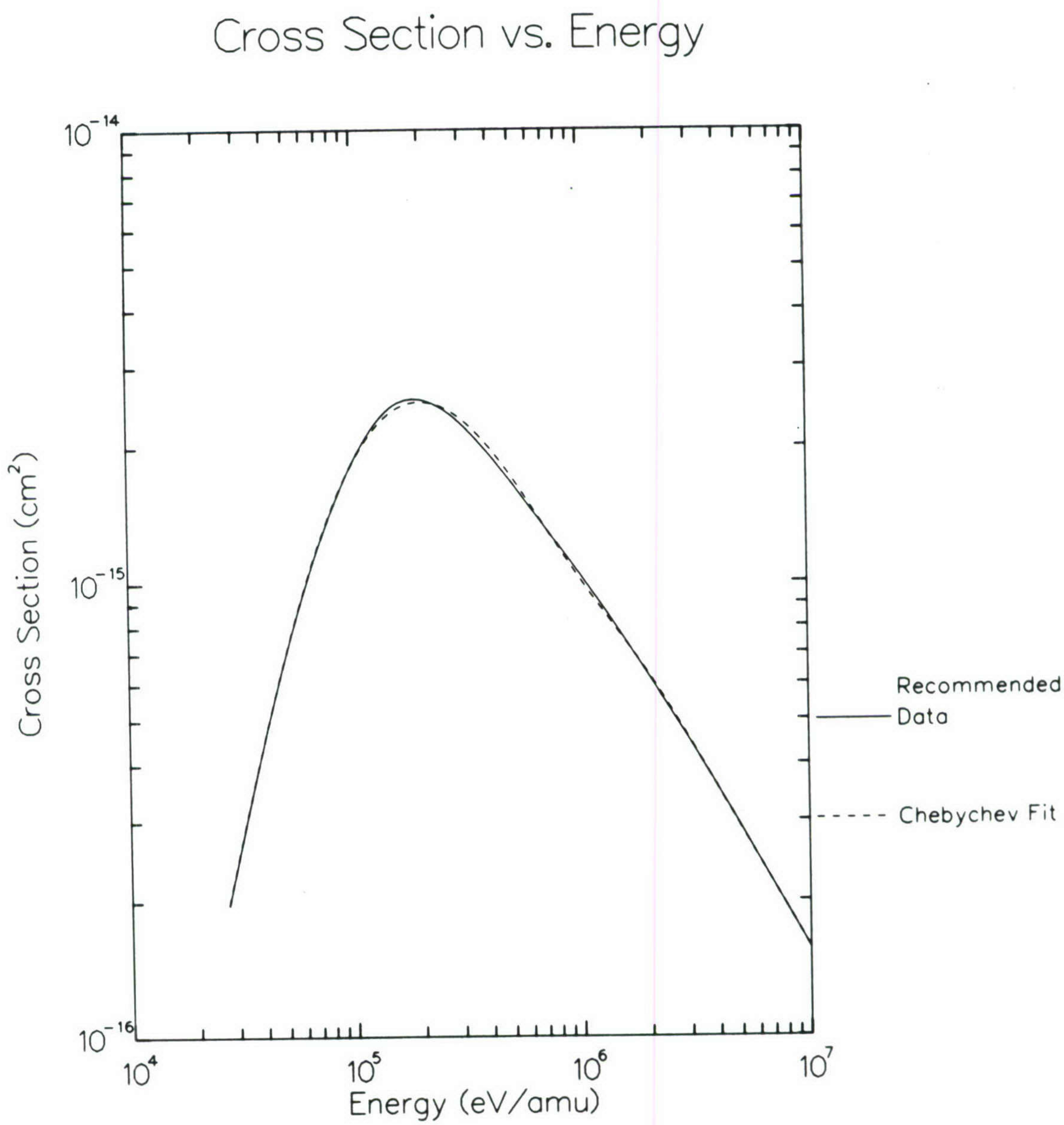
For Chebychev fits of the above cross sections it is necessary to use the following parameters.
E_{min} = 2.7E+04 eV/amu, E_{max} = 1.0E+07 eV/amu

Chebychev Fitting Parameters for Cross Sections

C1	C2	C3	C4	C5	C6	C7	C8	C9
1.749E-15	-3.354E-16	-8.390E-16	5.113E-16	1.170E-16	-2.640E-16	8.730E-17	6.961E-17	-6.406E-17

The fit represents the above cross sections with an rms deviation of 2.2%.
The maximum deviation is 4.4% at 4.0E+05 eV/amu.
See appendix for Chebychev fit details.

$O^{8+} + H \rightarrow O^{8+} + H^{+} + e^{-}$



Ionization Rate Coefficients for
$H + O^{8+} \rightarrow O^{8+} + H^+ + e^-$

Beam - Maxwellian Rate Coefficients (cm^3/s)

O^{8+} Temp. (eV)	H Energy (eV/amu) 20000.	40000.	70000.	100000.	200000.	400000.	500000.
1.0E+00	1.04E-08**	1.28E-07	4.41E-07	8.13E-07	1.57E-06	1.69E-06	1.65E-06
2.0E+00	1.04E-08**	1.28E-07	4.41E-07	8.13E-07	1.57E-06	1.69E-06	1.65E-06
4.0E+00	1.04E-08*	1.28E-07	4.41E-07	8.13E-07	1.57E-06	1.69E-06	1.65E-06
7.0E+00	1.05E-08*	1.28E-07	4.41E-07	8.13E-07	1.57E-06	1.69E-06	1.65E-06
1.0E+01	1.05E-08*	1.28E-07	4.41E-07	8.13E-07	1.57E-06	1.69E-06	1.65E-06
2.0E+01	1.06E-08*	1.28E-07	4.41E-07	8.13E-07	1.57E-06	1.69E-06	1.65E-06
4.0E+01	1.07E-08*	1.28E-07	4.41E-07	8.13E-07	1.57E-06	1.69E-06	1.65E-06
7.0E+01	1.08E-08*	1.28E-07	4.41E-07	8.13E-07	1.57E-06	1.69E-06	1.65E-06
1.0E+02	1.10E-08*	1.28E-07	4.41E-07	8.13E-07	1.57E-06	1.69E-06	1.65E-06
2.0E+02	1.12E-08*	1.28E-07	4.41E-07	8.13E-07	1.57E-06	1.69E-06	1.65E-06
4.0E+02	1.16E-08*	1.28E-07	4.42E-07	8.13E-07	1.57E-06	1.69E-06	1.65E-06
7.0E+02	1.21E-08*	1.29E-07	4.42E-07	8.13E-07	1.57E-06	1.69E-06	1.65E-06
1.0E+03	1.25E-08*	1.29E-07	4.42E-07	8.13E-07	1.57E-06	1.69E-06	1.65E-06
2.0E+03	1.36E-08*	1.30E-07	4.44E-07	8.14E-07	1.57E-06	1.69E-06	1.65E-06
4.0E+03	1.54E-08*	1.33E-07	4.46E-07	8.15E-07	1.57E-06	1.69E-06	1.65E-06
7.0E+03	1.78E-08*	1.37E-07	4.51E-07	8.18E-07	1.57E-06	1.69E-06	1.65E-06
1.0E+04	1.99E-08*	1.40E-07	4.55E-07	8.20E-07	1.57E-06	1.69E-06	1.65E-06
2.0E+04	2.70E-08*	1.53E-07	4.68E-07	8.28E-07	1.56E-06	1.69E-06	1.65E-06

Accuracy: * - Possible Error Greater Than 10%
** - Possible Error Greater Than 100%

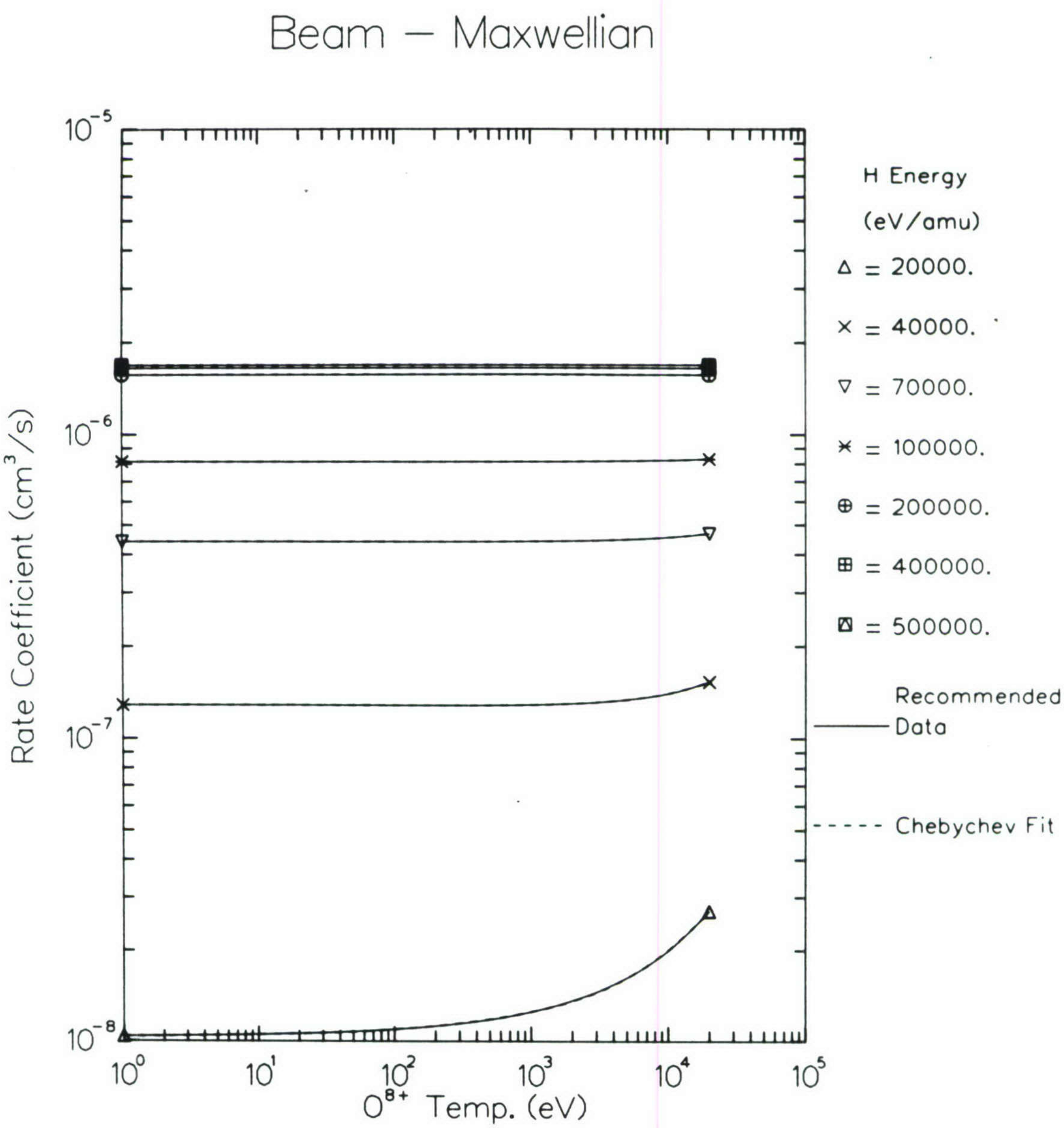
Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

Chebychev Fitting Parameters for Rate Coefficients

H Energy (eV/amu)	C1	C2	C3	C4	C5	C6	C7
20000.	2.807E-08	6.081E-09	3.671E-09	1.856E-09	8.410E-10	3.454E-10	1.237E-10
40000.	2.655E-07	8.062E-09	6.024E-09	3.640E-09	1.787E-09	7.142E-10	2.388E-10
70000.	8.920E-07	8.952E-09	6.399E-09	3.758E-09	1.829E-09	7.387E-10	2.537E-10
100000.	1.631E-06	5.006E-09	3.701E-09	2.203E-09	1.053E-09	3.988E-10	1.109E-10
200000.	3.132E-06	3.429E-10	-6.456E-10	-7.496E-10	-3.935E-10	-8.321E-11	3.761E-11
400000.	3.374E-06	1.125E-09	3.222E-10	-5.099E-11	-9.376E-11	-4.215E-11	7.382E-12
500000.	3.301E-06	-7.943E-10	-5.742E-10	-3.006E-10	-9.967E-11	1.095E-11	7.789E-11

See appendix for Chebychev fit details.

$H + O^{8+} \rightarrow O^{8+} + H^{+} + e^{-}$



Ionization Cross Sections for
$C^+ + He \rightarrow C^+ + He^+ + e^-$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
4.0E+04	2.78E+08	4.52E-17
7.0E+04	3.68E+08	7.67E-17
1.0E+05	4.39E+08	8.08E-17
2.0E+05	6.21E+08	5.98E-17
4.0E+05	8.78E+08	3.86E-17
7.0E+05	1.16E+09	2.64E-17
1.0E+06	1.39E+09	2.05E-17
2.0E+06	1.96E+09	1.23E-17
4.0E+06	2.77E+09	6.87E-18
7.0E+06	3.65E+09	4.34E-18
1.0E+07	4.36E+09	3.21E-18

References: T.9, T.59, T.60

Accuracy: 50% for $E < 7\times10^4$ eV/amu; 40% for $E \geq 7\times10^4$ eV/amu

Note: There are no experimental data for this reaction. The recommended cross section has been constructed by using the semi-empirical scaling formula of Ref. [T.60] with the fitting parameter determined from $H^+ + He$ and $Li^+ + He$ experimental data (see sect. 2.1.1). In the region around the maximum, the cross section obtained in this way is consistent (within 30%) with the calculation in Ref. [T.9], and those based on three-state close -coupling theory [T.59].

For Chebychev fits of the above cross sections it is necessary to use the following parameters.
E_{min} = 4.0E+04 eV/amu, E_{max} = 1.0E+07 eV/amu

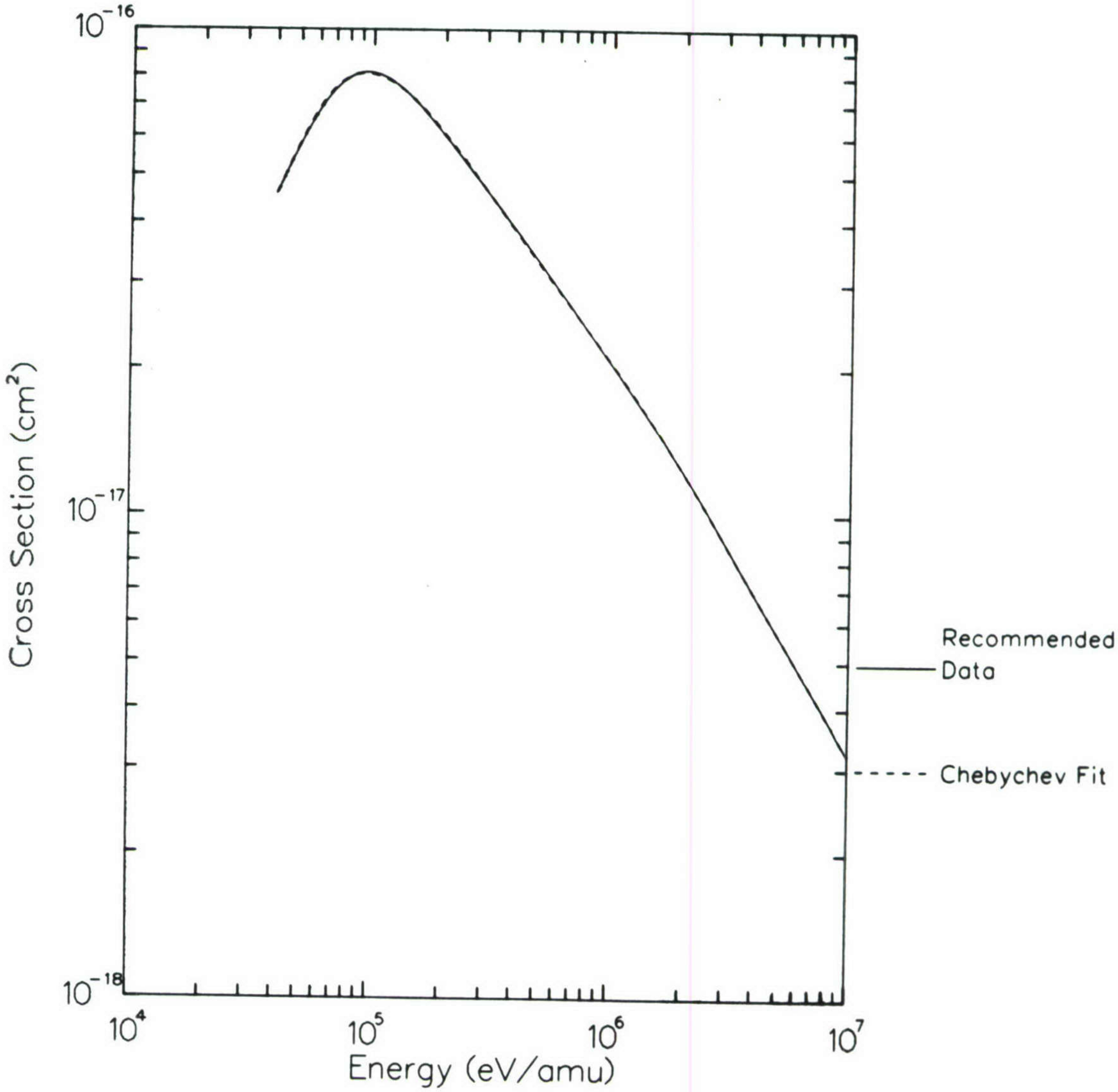
Chebychev Fitting Parameters for Cross Sections

C1	C2	C3	C4	C5	C6	C7	C8	C9
6.872E-17	-3.588E-17	-1.985E-18	1.263E-17	-8.724E-18	3.220E-18	4.648E-20	-9.454E-19	4.913E-19

The fit represents the above cross sections with an rms deviation of 0.9%.
The maximum deviation is 1.7% at 2.0E+05 eV/amu.
See appendix for Chebychev fit details.

$C^{+} + He \rightarrow C^{+} + He^{+} + e^{-}$

Cross Section vs. Energy



Ionization Rate Coefficients for
$He + C^{+} \rightarrow C^{+} + He^{+} + e^{-}$

Beam - Maxwellian Rate Coefficients (cm^3/s)

C^{+} Temp. (eV)	He Energy (eV/amu) 40000.	60000.	80000.	100000.	200000.	400000.	500000.
1.0E+00	6.30E-09**	2.38E-08	3.16E-08	3.55E-08	3.71E-08	3.39E-08	3.27E-08
2.0E+00	6.31E-09**	2.38E-08	3.16E-08	3.55E-08	3.71E-08	3.39E-08	3.27E-08
4.0E+00	6.33E-09**	2.38E-08	3.16E-08	3.55E-08	3.71E-08	3.39E-08	3.27E-08
7.0E+00	6.34E-09*	2.38E-08	3.16E-08	3.55E-08	3.71E-08	3.39E-08	3.27E-08
1.0E+01	6.36E-09*	2.38E-08	3.16E-08	3.55E-08	3.71E-08	3.39E-08	3.27E-08
2.0E+01	6.39E-09*	2.38E-08	3.16E-08	3.55E-08	3.72E-08	3.39E-08	3.27E-08
4.0E+01	6.44E-09*	2.38E-08	3.16E-08	3.55E-08	3.72E-08	3.39E-08	3.27E-08
7.0E+01	6.49E-09*	2.38E-08	3.16E-08	3.55E-08	3.72E-08	3.39E-08	3.27E-08
1.0E+02	6.53E-09*	2.38E-08	3.16E-08	3.55E-08	3.72E-08	3.39E-08	3.27E-08
2.0E+02	6.64E-09*	2.38E-08	3.16E-08	3.55E-08	3.72E-08	3.39E-08	3.27E-08
4.0E+02	6.79E-09*	2.38E-08	3.16E-08	3.55E-08	3.72E-08	3.39E-08	3.27E-08
7.0E+02	6.96E-09*	2.38E-08	3.16E-08	3.55E-08	3.72E-08	3.39E-08	3.27E-08
1.0E+03	7.10E-09*	2.38E-08	3.16E-08	3.55E-08	3.72E-08	3.39E-08	3.27E-08
2.0E+03	7.45E-09*	2.38E-08	3.16E-08	3.55E-08	3.72E-08	3.39E-08	3.27E-08
4.0E+03	7.98E-09*	2.38E-08	3.15E-08	3.54E-08	3.72E-08	3.39E-08	3.27E-08
7.0E+03	8.58E-09*	2.38E-08	3.14E-08	3.53E-08	3.72E-08	3.39E-08	3.26E-08
1.0E+04	9.07E-09*	2.38E-08	3.14E-08	3.52E-08	3.72E-08	3.39E-08	3.26E-08
2.0E+04	1.04E-08*	2.35E-08	3.10E-08	3.50E-08	3.72E-08	3.40E-08	3.27E-08

Accuracy: * - Possible Error Greater Than 10%
** - Possible Error Greater Than 100%

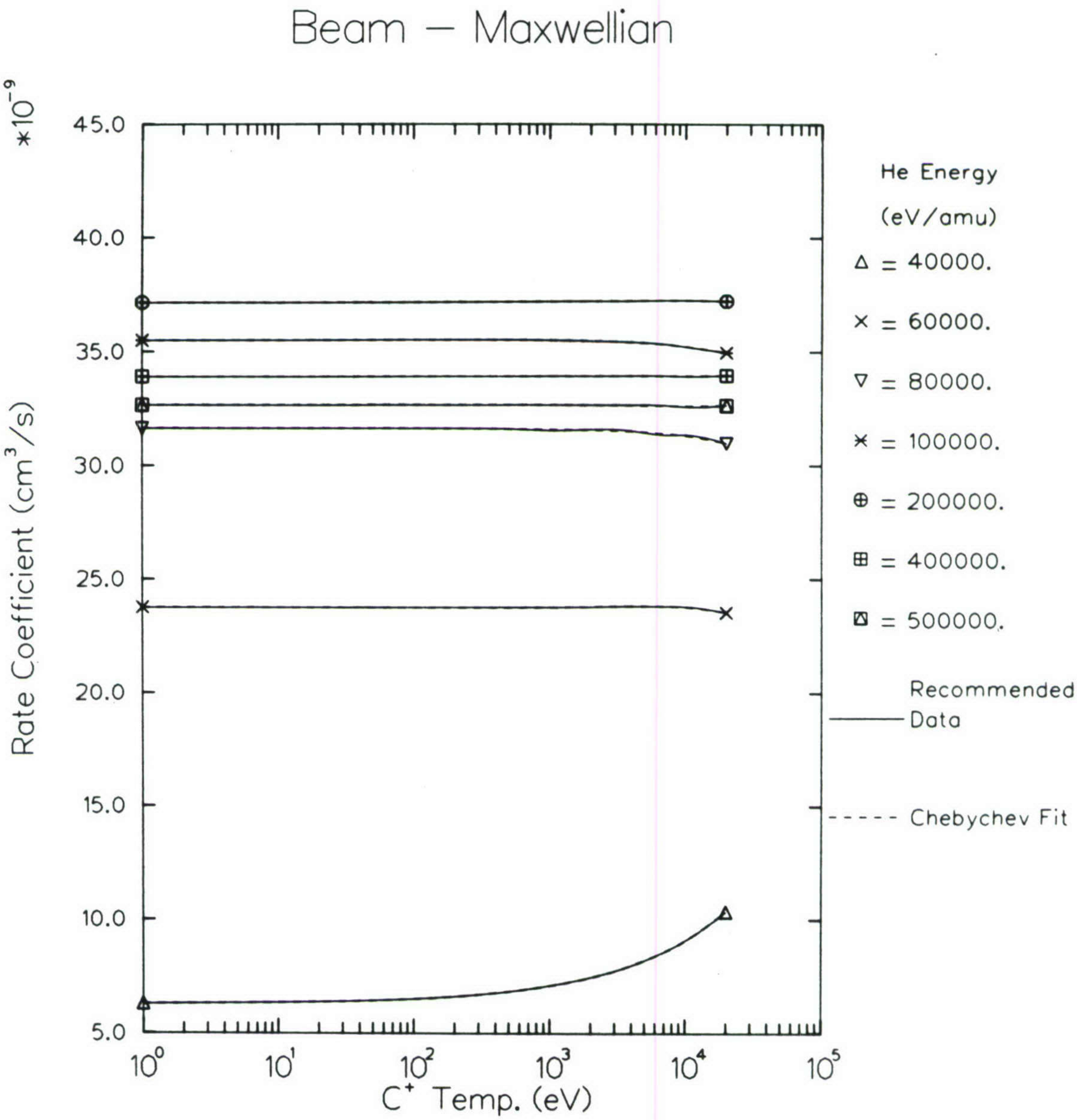
Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

Chebychev Fitting Parameters for Rate Coefficients

He Energy (eV/amu)	C1	C2	C3	C4	C5	C6	C7
40000.	1.468E-08	1.649E-09	8.694E-10	3.461E-10	1.110E-10	2.924E-11	5.828E-12
60000.	4.752E-08	-2.805E-11	-3.891E-11	-4.780E-11	-4.341E-11	-3.019E-11	-1.764E-11
80000.	6.305E-08	-2.154E-10	-1.505E-10	-8.707E-11	-4.419E-11	-2.169E-11	-9.994E-12
100000.	7.081E-08	-1.712E-10	-1.375E-10	-8.477E-11	-3.933E-11	-1.299E-11	-1.769E-12
200000.	7.436E-08	4.710E-11	1.093E-11	-6.315E-12	-7.933E-12	-5.087E-12	-3.426E-12
400000.	6.783E-08	2.077E-11	6.651E-12	1.485E-12	1.256E-12	2.385E-12	3.782E-12
500000.	6.531E-08	-1.571E-11	-1.166E-11	-3.264E-12	2.899E-12	5.984E-12	8.746E-12

See appendix for Chebychev fit details.

$He + C^{+} \rightarrow C^{+} + He^{+} + e^{-}$



Ionization Cross Sections for
$C^{2+} + He \rightarrow C^{2+} + He^{+} + e^{-}$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
4.6E+04	2.98E+08	6.18E-17
7.0E+04	3.68E+08	1.56E-16
1.0E+05	4.39E+08	1.98E-16
1.3E+05	5.01E+08	2.07E-16
2.0E+05	6.21E+08	1.90E-16
4.0E+05	8.78E+08	1.39E-16
7.0E+05	1.16E+09	1.01E-16
1.0E+06	1.39E+09	8.00E-17
2.0E+06	1.96E+09	4.87E-17
4.0E+06	2.77E+09	2.76E-17
7.0E+06	3.65E+09	1.75E-17
1.0E+07	4.36E+09	1.27E-17

References: T.9, T.59, T.60

Accuracy: 50% for $E < 7\times10^4$ eV/amu; 30% for $E \geq 7\times10^4$ eV/amu

Note: In the absence of experimental data, the recommended cross section has been constructed by using the semi-empirical scaling formula of Ref. [T.60], with the fitting parameter determined from experimental data on He^{2+} + He and Li^{2+} + He (see sect. 2.1.1). In the region near its maximum, the cross section so determined is consistent (to within 20%) with the calculations in Ref. [T.9], and those based on three-state close-coupling theory [T.59].

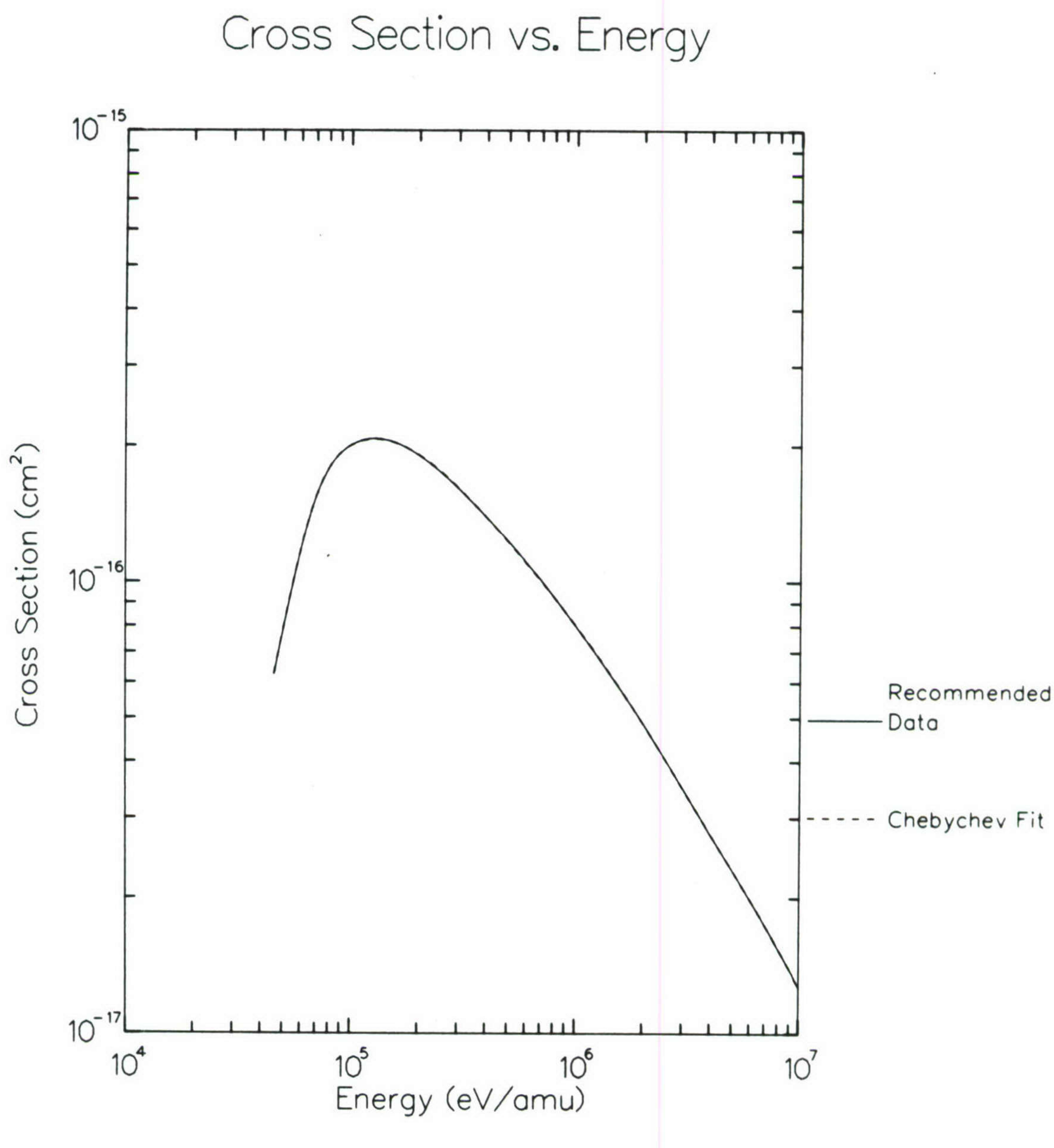
For Chebychev fits of the above cross sections it is necessary to use the following parameters.
E_{min} = 4.6E+04 eV/amu, E_{max} = 1.0E+07 eV/amu

Chebychev Fitting Parameters for Cross Sections

C1	C2	C3	C4	C5	C6	C7	C8	C9
1.799E-16	-7.148E-17	-3.411E-17	4.465E-17	-2.101E-17	4.576E-18	1.479E-18	-2.297E-18	9.504E-19

The fit represents the above cross sections with an rms deviation of 0.2%.
The maximum deviation is 0.4% at 1.0E+06 eV/amu.
See appendix for Chebychev fit details.

$C^{2+} + He \rightarrow C^{2+} + He^{+} + e^{-}$



Ionization Rate Coefficients for
$He + C^{2+} \rightarrow C^{2+} + He^{+} + e^{-}$

Beam - Maxwellian Rate Coefficients (cm^3/s)

C^{2+} Temp. (eV)	He Energy (eV/amu) 50000.	60000.	80000.	100000.	200000.	400000.	500000.
1.0E+00	2.44E-08	4.10E-08	7.11E-08	8.70E-08	1.18E-07	1.22E-07	1.21E-07
2.0E+00	2.44E-08	4.10E-08	7.11E-08	8.70E-08	1.18E-07	1.22E-07	1.21E-07
4.0E+00	2.44E-08	4.10E-08	7.11E-08	8.70E-08	1.18E-07	1.22E-07	1.21E-07
7.0E+00	2.44E-08	4.10E-08	7.11E-08	8.70E-08	1.18E-07	1.22E-07	1.21E-07
1.0E+01	2.44E-08	4.10E-08	7.11E-08	8.70E-08	1.18E-07	1.22E-07	1.21E-07
2.0E+01	2.44E-08	4.10E-08	7.11E-08	8.71E-08	1.18E-07	1.22E-07	1.21E-07
4.0E+01	2.44E-08	4.10E-08	7.11E-08	8.71E-08	1.18E-07	1.22E-07	1.21E-07
7.0E+01	2.44E-08	4.10E-08	7.11E-08	8.71E-08	1.18E-07	1.22E-07	1.21E-07
1.0E+02	2.44E-08	4.10E-08	7.11E-08	8.71E-08	1.18E-07	1.22E-07	1.21E-07
2.0E+02	2.44E-08	4.10E-08	7.11E-08	8.72E-08	1.18E-07	1.22E-07	1.21E-07
4.0E+02	2.43E-08	4.11E-08	7.10E-08	8.73E-08	1.18E-07	1.22E-07	1.21E-07
7.0E+02	2.39E-08	4.11E-08	7.10E-08	8.74E-08	1.18E-07	1.22E-07	1.21E-07
1.0E+03	2.35E-08	4.12E-08	7.10E-08	8.74E-08	1.18E-07	1.22E-07	1.21E-07
2.0E+03	2.27E-08*	4.14E-08	7.09E-08	8.75E-08	1.18E-07	1.22E-07	1.21E-07
4.0E+03	2.24E-08*	4.16E-08	7.07E-08	8.76E-08	1.18E-07	1.22E-07	1.21E-07
7.0E+03	2.30E-08*	4.18E-08	7.04E-08	8.76E-08	1.18E-07	1.22E-07	1.21E-07
1.0E+04	2.38E-08*	4.20E-08	7.02E-08	8.75E-08	1.18E-07	1.22E-07	1.21E-07
2.0E+04	2.65E-08*	4.29E-08	6.98E-08	8.73E-08	1.18E-07	1.22E-07	1.21E-07

Accuracy: * - Possible Error Greater Than 10%
** - Possible Error Greater Than 100%

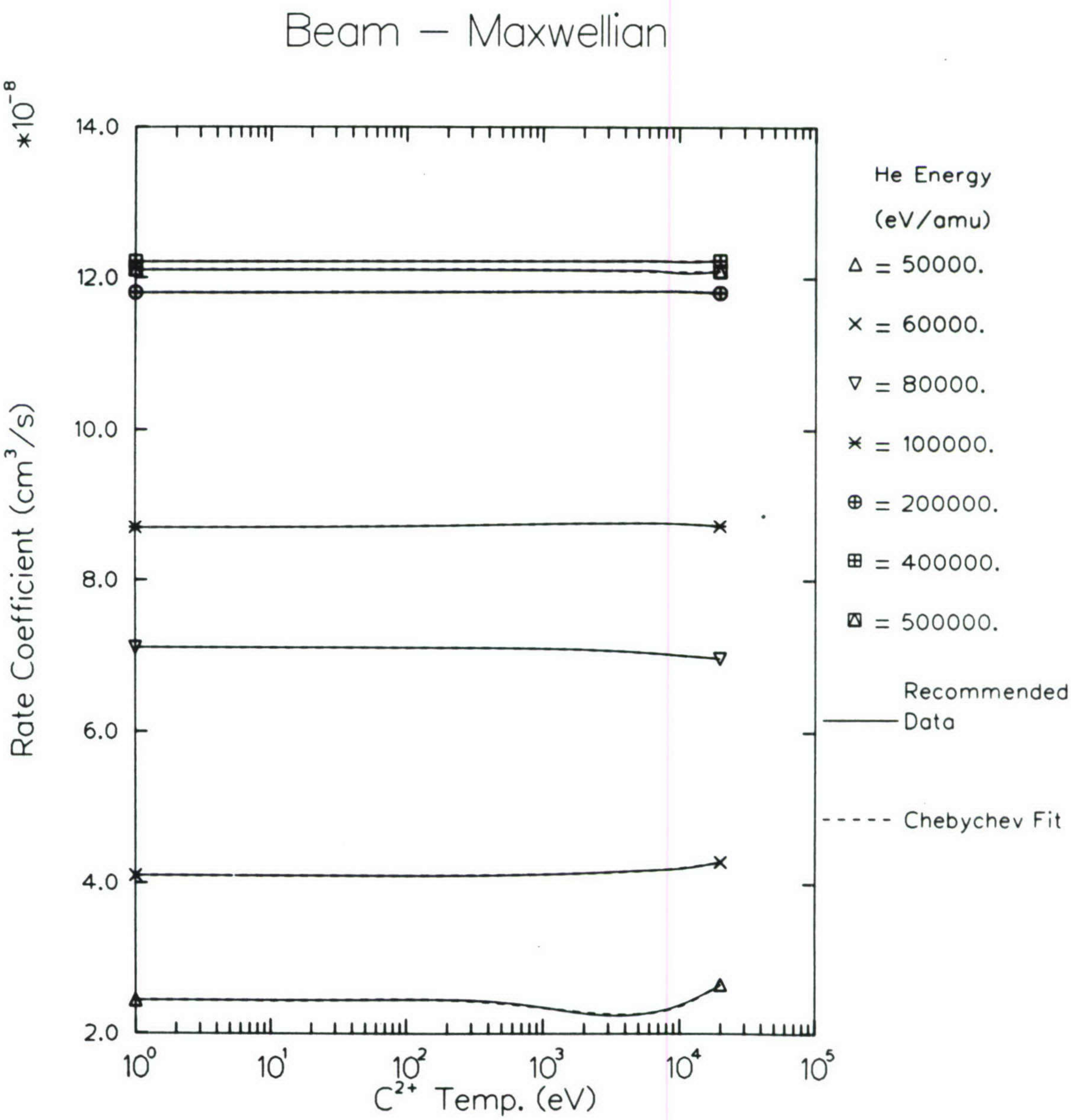
Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

Chebychev Fitting Parameters for Rate Coefficients

He Energy (eV/amu)	C1	C2	C3	C4	C5	C6	C7
50000.	4.848E-08	-8.048E-11	4.655E-10	8.168E-10	7.478E-10	3.823E-10	1.229E-11
60000.	8.273E-08	6.869E-10	4.338E-10	2.118E-10	8.408E-11	3.679E-11	3.253E-11
80000.	1.416E-07	-5.002E-10	-3.275E-10	-1.532E-10	-4.310E-11	2.449E-12	1.274E-11
100000.	1.745E-07	2.795E-10	-1.619E-11	-1.111E-10	-7.948E-11	-3.309E-11	-9.742E-12
200000.	2.362E-07	9.867E-11	-2.522E-13	-3.984E-11	-3.458E-11	-1.995E-11	-1.239E-11
400000.	2.443E-07	8.710E-11	2.632E-11	3.464E-12	2.685E-12	7.734E-12	1.358E-11
500000.	2.420E-07	-7.027E-11	-5.186E-11	-1.694E-11	8.677E-12	2.166E-11	3.268E-11

See appendix for Chebychev fit details.

$He + C^{2+} \rightarrow C^{2+} + He^{+} + e^{-}$



Ionization Cross Sections for
$C^{3+} + He \rightarrow C^{3+} + He^{+} + e^{-}$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
5.0E+04	3.07E+08	6.33E-17
7.0E+04	3.68E+08	1.61E-16
1.0E+05	4.39E+08	2.74E-16
2.0E+05	6.21E+08	3.58E-16
4.0E+05	8.78E+08	2.98E-16
7.0E+05	1.16E+09	2.22E-16
1.0E+06	1.39E+09	1.78E-16
2.0E+06	1.96E+09	1.09E-16
4.0E+06	2.77E+09	6.23E-17
7.0E+06	3.65E+09	3.90E-17
1.0E+07	4.36E+09	2.89E-17

References: E.67, T.9, T.59, T.60

Accuracy: 40% for $E < 1x10^5$ eV/amu; 30% for $E \geq 1x10^5$ eV/amu

Note: The recommended cross section for this reaction has been constructed by using the semi-empirical scaling formula [T.60] with the fitting parameters determined from the single measurement at 640 keV/amu [E.67] and Li^{3+} + He experimental data (see sect. 2.1.1). In the region $1.2x10^5 \leq E(eV/amu) \leq 1x10^6$, the cross section so determined coincides (to within 5%) with the calculations based on three-state close-coupling theory [T.59], and (to within 25%) with the classical-trajectory Monte Carlo calculations [T.9] at $E = 1x10^5$ eV/amu.

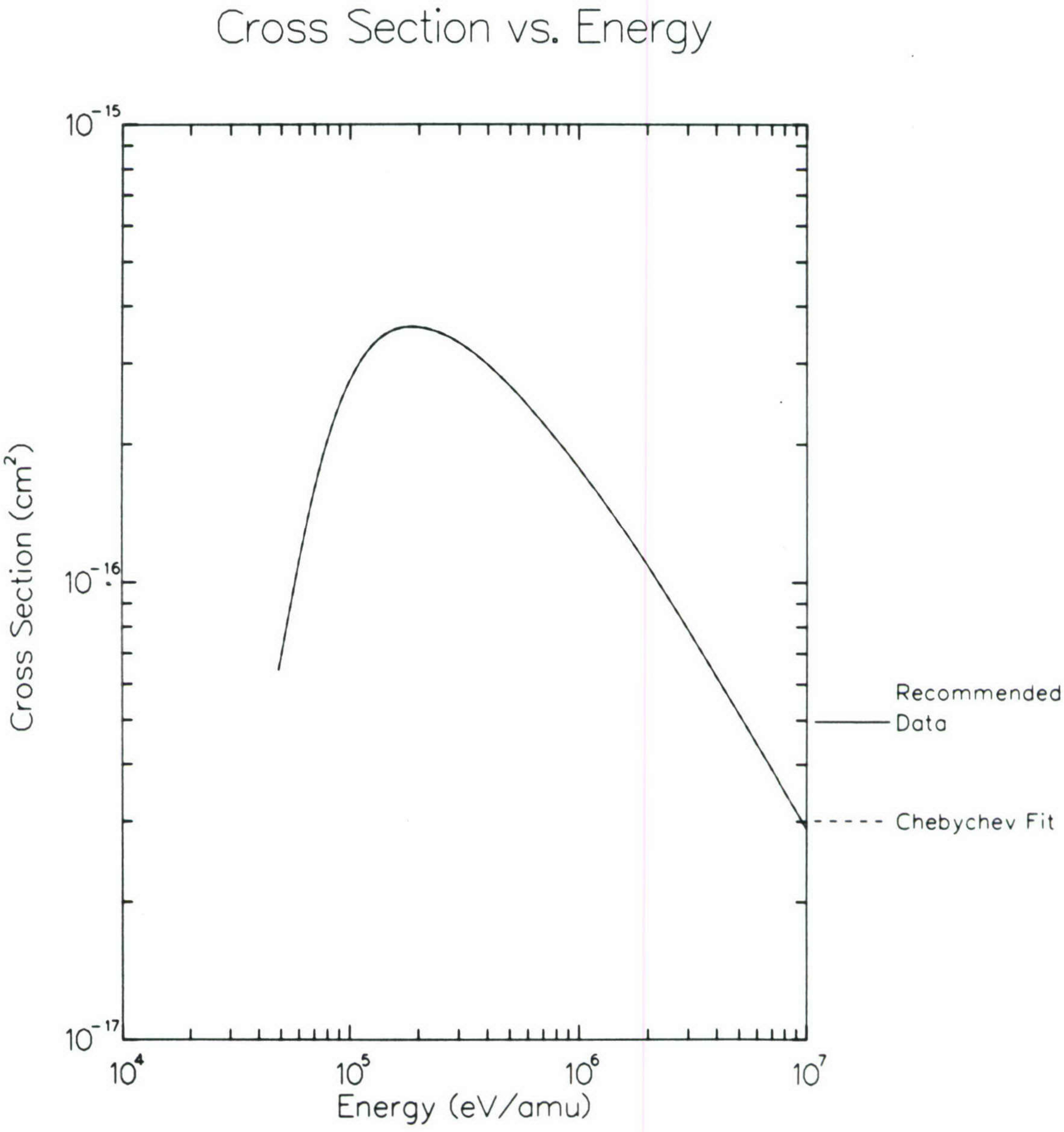
For Chebychev fits of the above cross sections it is necessary to use the following parameters.
E_{min} = 4.9E+04 eV/amu, E_{max} = 1.0E+07 eV/amu

Chebychev Fitting Parameters for Cross Sections

C1	C2	C3	C4	C5	C6	C7	C8	C9
3.046E-16	-8.600E-17	-9.963E-17	8.443E-17	-1.946E-17	-9.940E-18	1.161E-17	-5.693E-18	1.309E-18

The fit represents the above cross sections with an rms deviation of 0.0%.
The maximum deviation is 0.1% at 7.0E+05 eV/amu.
See appendix for Chebychev fit details.

$C^{3+} + He \rightarrow C^{3+} + He^{+} + e^{-}$



Ionization Rate Coefficients for
$He + C^{3+} \rightarrow C^{3+} + He^{+} + e^{-}$

Beam - Maxwellian Rate Coefficients (cm^3/s)

C^{3+} Temp. (eV)	He Energy (eV/amu) 50000.	60000.	80000.	100000.	200000.	400000.	500000.
1.0E+00	2.09E-08	3.84E-08	8.09E-08	1.20E-07	2.22E-07	2.62E-07	2.64E-07
2.0E+00	2.10E-08	3.84E-08	8.09E-08	1.20E-07	2.22E-07	2.62E-07	2.64E-07
4.0E+00	2.10E-08	3.84E-08	8.09E-08	1.20E-07	2.22E-07	2.62E-07	2.64E-07
7.0E+00	2.10E-08	3.84E-08	8.09E-08	1.20E-07	2.22E-07	2.62E-07	2.64E-07
1.0E+01	2.10E-08	3.84E-08	8.09E-08	1.20E-07	2.22E-07	2.62E-07	2.64E-07
2.0E+01	2.08E-08	3.85E-08	8.09E-08	1.20E-07	2.23E-07	2.62E-07	2.64E-07
4.0E+01	2.02E-08	3.85E-08	8.09E-08	1.20E-07	2.23E-07	2.62E-07	2.64E-07
7.0E+01	1.92E-08	3.85E-08	8.09E-08	1.20E-07	2.23E-07	2.62E-07	2.64E-07
1.0E+02	1.85E-08*	3.85E-08	8.09E-08	1.20E-07	2.23E-07	2.62E-07	2.64E-07
2.0E+02	1.71E-08*	3.85E-08	8.09E-08	1.21E-07	2.23E-07	2.62E-07	2.64E-07
4.0E+02	1.60E-08*	3.86E-08	8.10E-08	1.21E-07	2.23E-07	2.62E-07	2.64E-07
7.0E+02	1.55E-08*	3.87E-08	8.10E-08	1.21E-07	2.23E-07	2.62E-07	2.64E-07
1.0E+03	1.54E-08*	3.88E-08	8.11E-08	1.21E-07	2.23E-07	2.62E-07	2.64E-07
2.0E+03	1.57E-08*	3.92E-08	8.13E-08	1.21E-07	2.24E-07	2.62E-07	2.64E-07
4.0E+03	1.67E-08*	3.95E-08	8.17E-08	1.21E-07	2.24E-07	2.62E-07	2.64E-07
7.0E+03	1.83E-08*	4.01E-08	8.23E-08	1.22E-07	2.24E-07	2.62E-07	2.64E-07
1.0E+04	1.98E-08*	4.08E-08	8.30E-08	1.22E-07	2.25E-07	2.62E-07	2.63E-07
2.0E+04	2.42E-08*	4.37E-08	8.50E-08	1.23E-07	2.25E-07	2.63E-07	2.64E-07

Accuracy: * - Possible Error Greater Than 10%
** - Possible Error Greater Than 100%

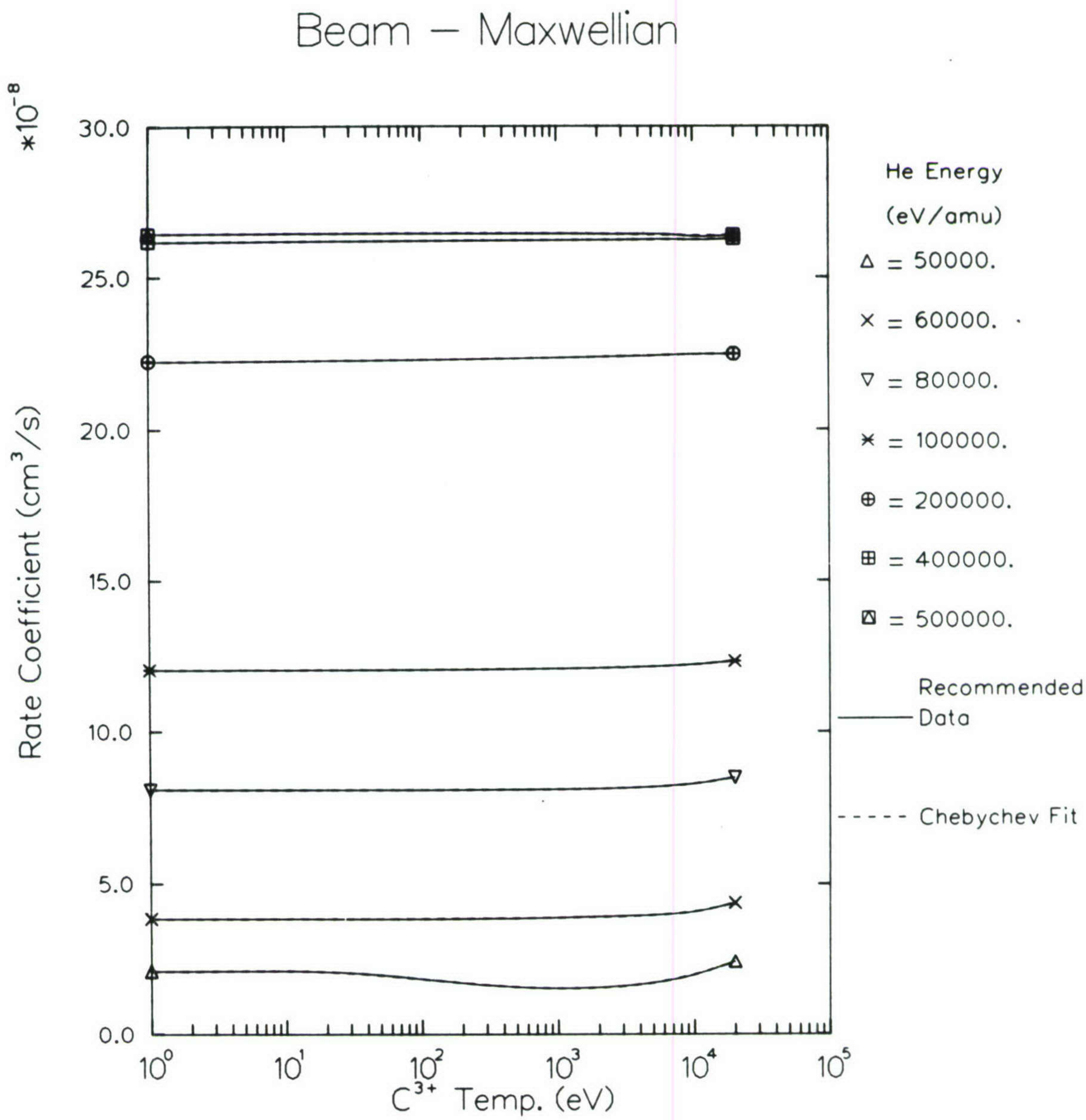
Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

Chebychev Fitting Parameters for Rate Coefficients

He Energy (eV/amu)	C1	C2	C3	C4	C5	C6	C7
50000.	3.923E-08	-6.127E-10	2.293E-09	2.405E-09	5.950E-10	-2.290E-10	8.819E-11
60000.	7.879E-08	1.699E-09	1.167E-09	6.914E-10	3.772E-10	2.072E-10	1.259E-10
80000.	1.633E-07	1.349E-09	9.629E-10	5.684E-10	2.776E-10	1.141E-10	3.879E-11
100000.	2.420E-07	1.158E-09	5.894E-10	3.678E-10	9.308E-11	8.535E-11	-5.952E-12
200000.	4.464E-07	1.164E-09	4.268E-10	3.378E-11	-6.000E-11	-4.761E-11	-2.976E-11
400000.	5.241E-07	4.284E-10	1.531E-10	2.431E-11	7.541E-13	1.134E-11	2.694E-11
500000.	5.283E-07	-2.120E-10	-1.550E-10	-6.126E-11	7.440E-12	4.295E-11	7.030E-11

See appendix for Chebychev fit details.

$He + C^{3+} \rightarrow C^{3+} + He^{+} + e^{-}$



Ionization Cross Sections for
$C^{4+} + He \rightarrow C^{4+} + He^{+} + e^{-}$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
5.5E+04	3.26E+08	2.16E-16
7.0E+04	3.68E+08	2.75E-16
1.0E+05	4.39E+08	3.71E-16
2.0E+05	6.21E+08	4.72E-16
4.0E+05	8.78E+08	4.31E-16
7.0E+05	1.16E+09	3.63E-16
1.0E+06	1.39E+09	3.02E-16
2.0E+06	1.96E+09	2.02E-16
4.0E+06	2.77E+09	1.18E-16
7.0E+06	3.65E+09	7.11E-17
1.0E+07	4.36E+09	5.07E-17

References: E.67, E.68, T.9, T.59, T.60

Accuracy: 40% for $E < 1\times10^5$ eV/amu; 15% for $E \geq 1\times10^5$ eV/amu

Note: In the region $1.2\times10^5 \leq E(\text{eV/amu}) \leq 1.5\times10^6$, the recommended cross section represents the experimental data [E.67], [E.68], which coincide within the stated uncertainty with the results of the three-state close-coupling theory [T.59]. In the region above 1.5×10^6 eV/amu, the cross section is given by the semi-empirical scaling formula (see sect. 2.1.1) which preserves the correct Bethe-Born high-energy cross section behavior.

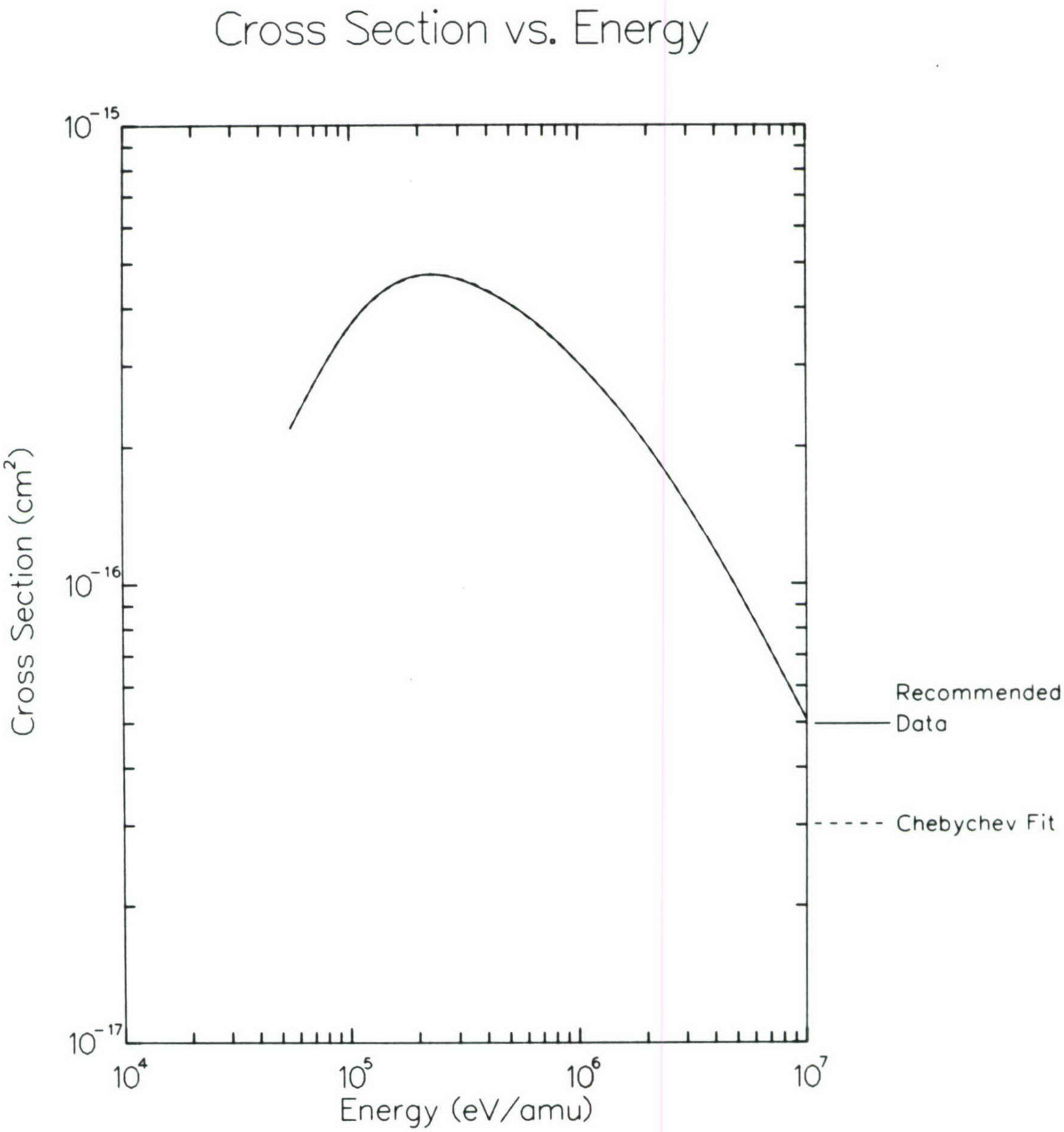
For Chebychev fits of the above cross sections it is necessary to use the following parameters.
E_{min} = 5.5E+04 eV/amu, E_{max} = 1.0E+07 eV/amu

Chebychev Fitting Parameters for Cross Sections

C1	C2	C3	C4	C5	C6	C7	C8	C9
4.967E-16	-1.466E-16	-1.149E-16	7.529E-17	-7.137E-18	-8.525E-18	6.551E-18	-2.831E-18	4.851E-19

The fit represents the above cross sections with an rms deviation of 0.5%.
The maximum deviation is 0.9% at 4.0E+05 eV/amu.
See appendix for Chebychev fit details.

$C^{4+} + He \rightarrow C^{4+} + He^{+} + e^{-}$



Ionization Rate Coefficients for
$He + C^{4+} \rightarrow C^{4+} + He^{+} + e^{-}$

Beam - Maxwellian Rate Coefficients (cm^3/s)

C^{4+} Temp. (eV)	He Energy (eV/amu) 60000.	70000.	80000.	100000.	200000.	400000.	500000.
1.0E+00	8.06E-08	1.01E-07	1.22E-07	1.63E-07	2.93E-07	3.79E-07	3.99E-07
2.0E+00	8.05E-08	1.01E-07	1.22E-07	1.63E-07	2.93E-07	3.79E-07	3.99E-07
4.0E+00	8.05E-08	1.01E-07	1.22E-07	1.63E-07	2.93E-07	3.79E-07	3.99E-07
7.0E+00	8.05E-08	1.01E-07	1.22E-07	1.63E-07	2.93E-07	3.79E-07	3.99E-07
1.0E+01	8.05E-08	1.01E-07	1.22E-07	1.63E-07	2.93E-07	3.79E-07	3.99E-07
2.0E+01	8.05E-08	1.01E-07	1.22E-07	1.63E-07	2.93E-07	3.79E-07	3.99E-07
4.0E+01	8.05E-08	1.01E-07	1.22E-07	1.63E-07	2.93E-07	3.79E-07	3.99E-07
7.0E+01	8.05E-08	1.01E-07	1.22E-07	1.63E-07	2.93E-07	3.79E-07	3.99E-07
1.0E+02	8.05E-08	1.01E-07	1.22E-07	1.63E-07	2.93E-07	3.79E-07	3.99E-07
2.0E+02	8.05E-08	1.01E-07	1.22E-07	1.63E-07	2.93E-07	3.79E-07	3.99E-07
4.0E+02	8.02E-08	1.01E-07	1.22E-07	1.63E-07	2.93E-07	3.79E-07	3.99E-07
7.0E+02	7.89E-08	1.01E-07	1.22E-07	1.63E-07	2.93E-07	3.79E-07	3.99E-07
1.0E+03	7.73E-08	1.01E-07	1.22E-07	1.63E-07	2.93E-07	3.79E-07	3.99E-07
2.0E+03	7.32E-08*	1.02E-07	1.22E-07	1.63E-07	2.94E-07	3.79E-07	3.99E-07
4.0E+03	6.92E-08*	1.02E-07	1.23E-07	1.63E-07	2.94E-07	3.79E-07	3.99E-07
7.0E+03	6.72E-08*	1.01E-07	1.23E-07	1.64E-07	2.94E-07	3.79E-07	3.99E-07
1.0E+04	6.69E-08*	1.00E-07	1.24E-07	1.64E-07	2.94E-07	3.79E-07	3.98E-07
2.0E+04	6.88E-08*	9.91E-08	1.24E-07	1.65E-07	2.94E-07	3.80E-07	3.99E-07

Accuracy: * - Possible Error Greater Than 10%
** - Possible Error Greater Than 100%

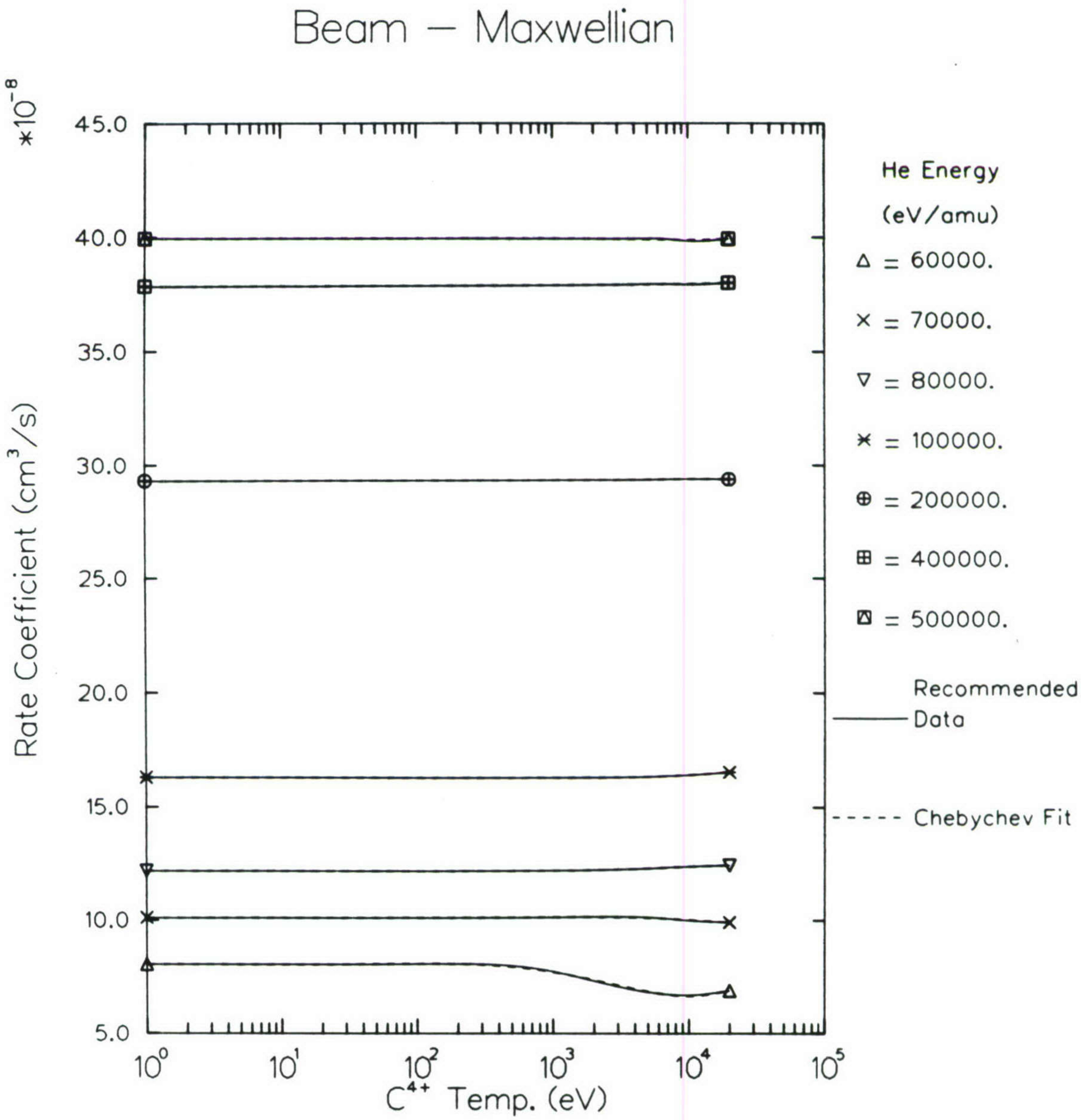
Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

Chebychev Fitting Parameters for Rate Coefficients

He Energy (eV/amu)	C1	C2	C3	C4	C5	C6	C7
60000.	1.525E-07	-6.995E-09	-3.325E-09	-1.712E-11	1.551E-09	1.258E-09	2.665E-10
70000.	2.017E-07	-4.932E-10	-5.519E-10	-4.680E-10	-2.675E-10	-7.559E-11	8.087E-11
80000.	2.449E-07	1.071E-09	6.734E-10	2.695E-10	2.695E-11	-5.746E-11	-6.158E-11
100000.	3.268E-07	6.903E-10	6.593E-10	3.295E-10	2.310E-10	4.188E-11	4.591E-11
200000.	5.868E-07	3.184E-10	1.133E-10	-2.292E-13	-2.742E-11	-2.379E-11	-2.244E-11
400000.	7.579E-07	5.735E-10	2.354E-10	6.880E-11	2.741E-11	3.031E-11	4.604E-11
500000.	7.985E-07	-2.001E-10	-1.486E-10	-4.035E-11	3.900E-11	7.859E-11	1.143E-10

See appendix for Chebychev fit details.

$He + C^{4+} \rightarrow C^{4+} + He^{+} + e^{-}$



Ionization Cross Sections for
$C^{5+} + He \rightarrow C^{5+} + He^{+} + e^{-}$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
4.9E+04	3.07E+08	1.09E-16
7.0E+04	3.68E+08	1.95E-16
1.0E+05	4.39E+08	3.26E-16
2.0E+05	6.21E+08	6.21E-16
2.9E+05	7.48E+08	6.76E-16
4.0E+05	8.78E+08	6.37E-16
7.0E+05	1.16E+09	5.19E-16
1.0E+06	1.39E+09	4.37E-16
2.0E+06	1.96E+09	2.86E-16
4.0E+06	2.77E+09	1.70E-16
7.0E+06	3.65E+09	1.06E-16
1.0E+07	4.36E+09	7.85E-17

References: E.67, E.68, T.9, T.59, T.60

Accuracy: 40% for $E < 1 \times 10^5$ eV/amu; 20% for $1 \times 10^5 \leq E$(eV/amu) $< 4 \times 10^6$; 15% for $E \geq 4 \times 10^6$ eV/amu

Note: In the region above 1×10^5 eV/amu, the recommended cross section is constructed on the basis of experimental data [E.67], [E.68], and within the indicated uncertainties, it agrees with the three-state close-coupling theory [T.59] (up to 3×10^6 eV/amu) and with the semi-empirical scaling formula [T.60] (down to 2×10^5 eV/amu).

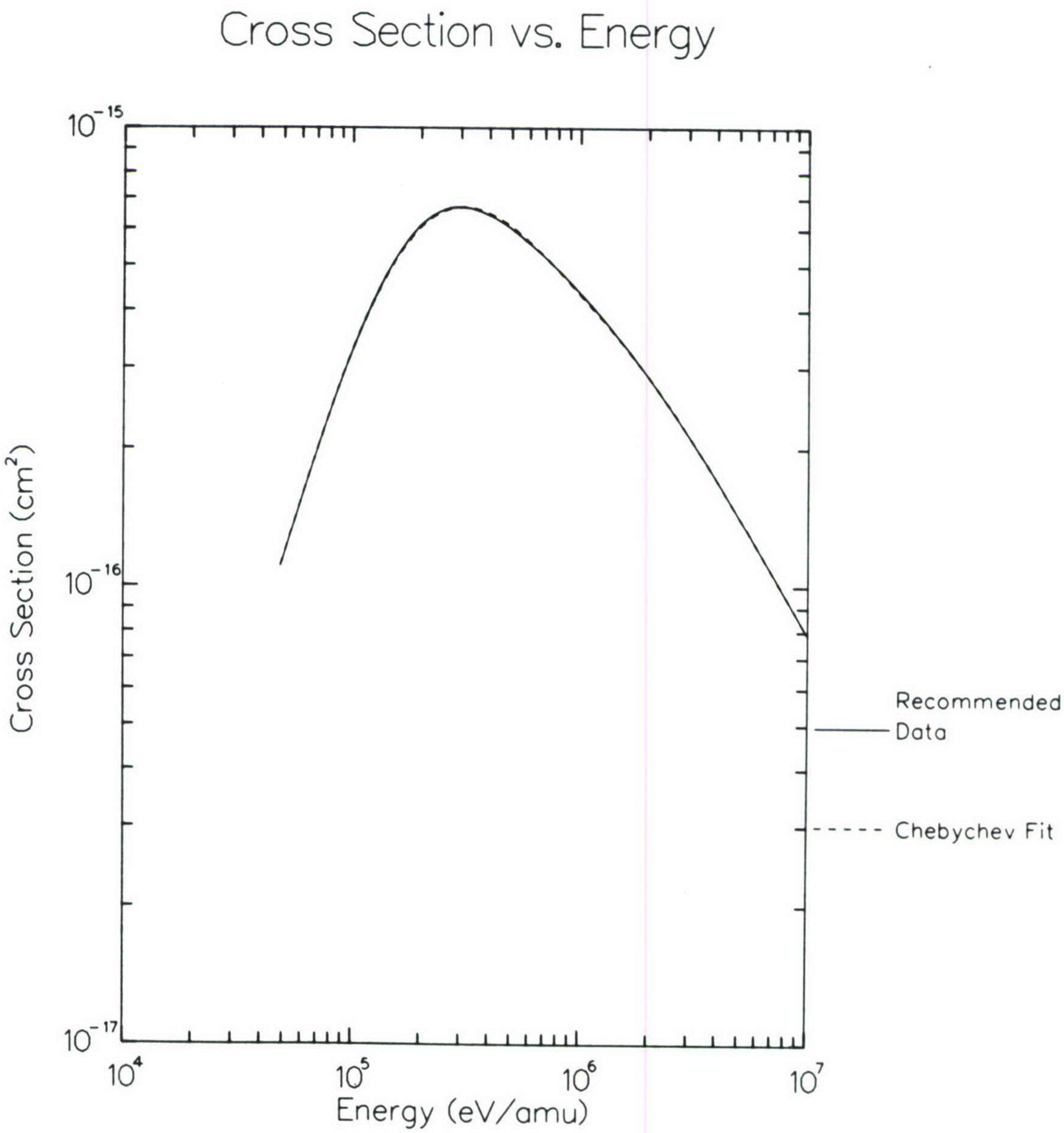
For Chebychev fits of the above cross sections it is necessary to use the following parameters.
E_{min} = 4.9E+04 eV/amu, E_{max} = 1.0E+07 eV/amu

Chebychev Fitting Parameters for Cross Sections

C1	C2	C3	C4	C5	C6	C7	C8	C9
5.823E-16	-8.921E-17	-2.311E-16	1.122E-16	2.724E-17	-4.590E-17	1.698E-17	7.669E-18	-1.045E-17

The fit represents the above cross sections with an rms deviation of 0.9%.
The maximum deviation is 1.9% at 4.0E+05 eV/amu.
See appendix for Chebychev fit details.

$C^{5+} + He \rightarrow C^{5+} + He^{+} + e^{-}$



Ionization Rate Coefficients for
$He + C^{5+} \rightarrow C^{5+} + He^{+} + e^{-}$

Beam - Maxwellian Rate Coefficients (cm^3/s)

C^{5+} Temp. (eV)	He Energy (eV/amu) 50000.	60000.	80000.	100000.	200000.	400000.	500000.
1.0E+00	3.51E-08	5.16E-08	9.25E-08	1.43E-07	3.77E-07	5.59E-07	5.85E-07
2.0E+00	3.50E-08	5.20E-08	9.36E-08	1.43E-07	3.86E-07	5.59E-07	5.85E-07
4.0E+00	3.51E-08	5.20E-08	9.36E-08	1.43E-07	3.86E-07	5.60E-07	5.85E-07
7.0E+00	3.51E-08	5.20E-08	9.36E-08	1.43E-07	3.86E-07	5.60E-07	5.85E-07
1.0E+01	3.50E-08	5.20E-08	9.36E-08	1.43E-07	3.86E-07	5.60E-07	5.85E-07
2.0E+01	3.48E-08	5.20E-08	9.36E-08	1.43E-07	3.86E-07	5.60E-07	5.85E-07
4.0E+01	3.37E-08	5.20E-08	9.36E-08	1.43E-07	3.86E-07	5.60E-07	5.85E-07
7.0E+01	3.20E-08	5.21E-08	9.36E-08	1.43E-07	3.86E-07	5.60E-07	5.85E-07
1.0E+02	3.07E-08*	5.21E-08	9.36E-08	1.43E-07	3.86E-07	5.60E-07	5.85E-07
2.0E+02	2.82E-08*	5.21E-08	9.37E-08	1.43E-07	3.86E-07	5.60E-07	5.85E-07
4.0E+02	2.61E-08*	5.22E-08	9.38E-08	1.43E-07	3.85E-07	5.60E-07	5.85E-07
7.0E+02	2.50E-08*	5.23E-08	9.39E-08	1.43E-07	3.85E-07	5.60E-07	5.85E-07
1.0E+03	2.45E-08*	5.24E-08	9.40E-08	1.43E-07	3.85E-07	5.60E-07	5.85E-07
2.0E+03	2.43E-08*	5.26E-08	9.44E-08	1.44E-07	3.85E-07	5.60E-07	5.85E-07
4.0E+03	2.50E-08*	5.26E-08	9.53E-08	1.44E-07	3.85E-07	5.60E-07	5.85E-07
7.0E+03	2.63E-08*	5.25E-08	9.65E-08	1.45E-07	3.85E-07	5.60E-07	5.85E-07
1.0E+04	2.78E-08*	5.27E-08	9.77E-08	1.47E-07	3.85E-07	5.60E-07	5.84E-07
2.0E+04	3.21E-08*	5.50E-08	1.01E-07	1.50E-07	3.84E-07	5.60E-07	5.85E-07

Accuracy: * - Possible Error Greater Than 10%
** - Possible Error Greater Than 100%

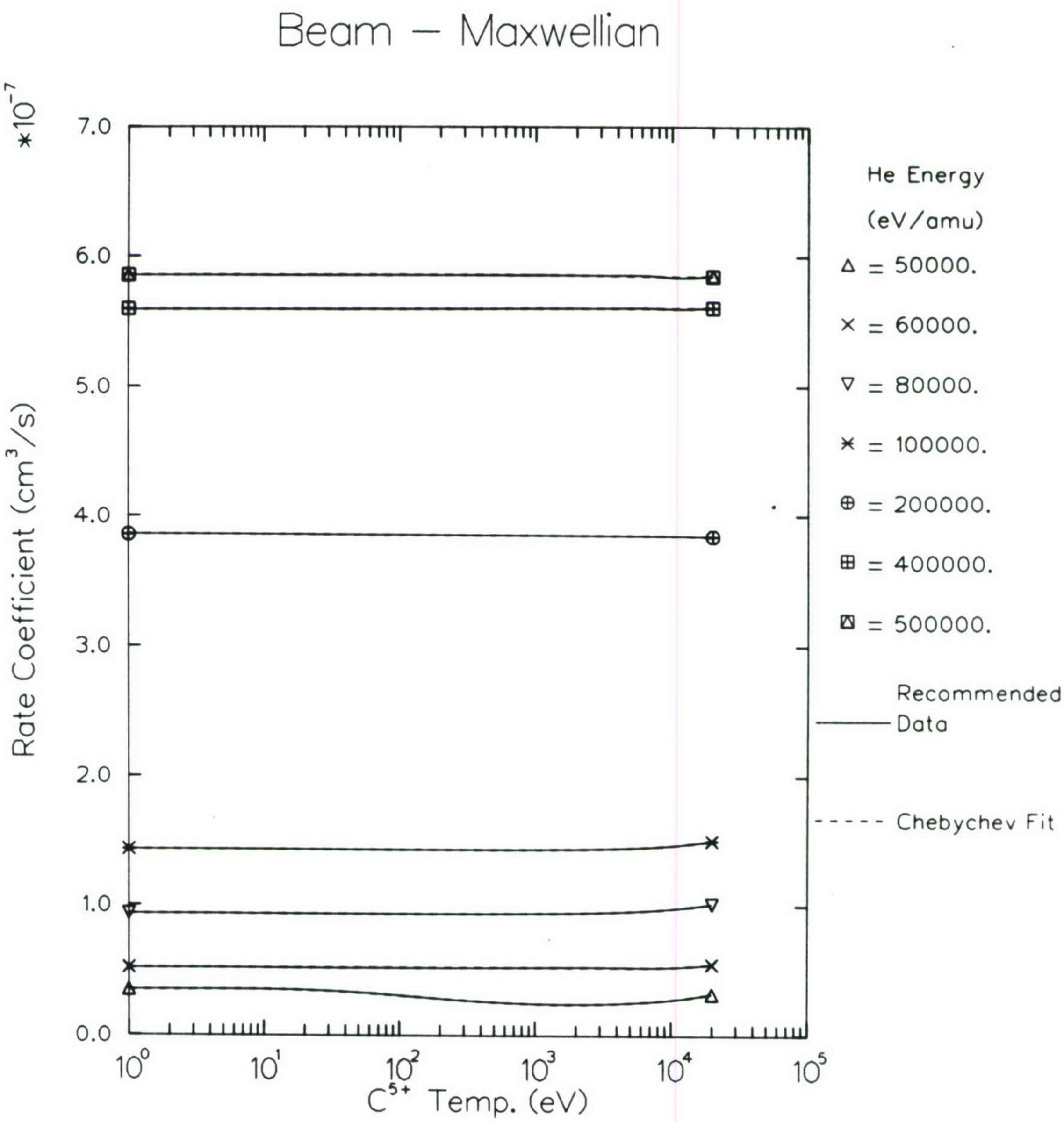
Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

Chebychev Fitting Parameters for Rate Coefficients

He Energy (eV/amu)	C1	C2	C3	C4	C5	C6	C7
50000.	6.175E-08	-4.306E-09	1.932E-09	3.186E-09	7.111E-10	-5.035E-10	1.456E-10
60000.	1.049E-07	9.068E-10	4.495E-10	4.235E-10	2.140E-10	2.746E-10	1.591E-10
80000.	1.899E-07	2.861E-09	1.654E-09	1.250E-09	3.425E-10	2.985E-10	-3.715E-11
100000.	2.888E-07	2.237E-09	1.662E-09	1.005E-09	4.976E-10	2.020E-10	6.938E-11
200000.	7.688E-07	1.121E-09	-1.839E-09	1.355E-09	-1.174E-09	8.659E-10	-6.806E-10
400000.	1.120E-06	4.588E-10	9.902E-11	-2.901E-11	-1.873E-11	2.198E-11	5.981E-11
500000.	1.170E-06	-4.048E-10	-2.975E-10	-1.070E-10	3.265E-11	1.041E-10	1.621E-10

See appendix for Chebychev fit details.

$He + C^{5+} \rightarrow C^{5+} + He^{+} + e^{-}$



Ionization Cross Sections for
$C^{6+} + He \rightarrow C^{6+} + He^{+} + e^{-}$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
7.0E+04	3.68E+08	1.59E-16
1.0E+05	4.39E+08	3.16E-16
2.0E+05	6.21E+08	7.35E-16
3.1E+05	7.73E+08	8.68E-16
4.0E+05	8.78E+08	8.50E-16
7.0E+05	1.16E+09	6.78E-16
1.0E+06	1.39E+09	5.66E-16
2.0E+06	1.96E+09	3.75E-16
4.0E+06	2.77E+09	2.29E-16
7.0E+06	3.65E+09	1.51E-16
1.0E+07	4.36E+09	1.14E-16

References: E.67, E.68, T.9, T.42, T.57, T.59, T.60, T.61

Accuracy: 40% for $E < 2x10^5$ eV/amu; 20% for $2x10^5 \leq E$(eV/amu) $< 5x10^5$; 15% for $E \geq 5x10^5$ eV/amu

Note: For $E \geq 2x10^5$ eV/amu, the cross section has been constructed on the basis of experimental data [E.67], [E.68], which agree (within the indicated accuracies) with the semi-empirical scaling formula (see sect. 2.1.1), three-state close-coupling theory [T.59] and classical-trajectory Monte Carlo calculations [T.61]. Below $2x10^5$ eV/amu, the cross section has been constructed on the basis of theoretical data from [T.59] and [T.42]

For Chebychev fits of the above cross sections it is necessary to use the following parameters.
E_{min} = 7.0E+04 eV/amu, E_{max} = 1.0E+07 eV/amu

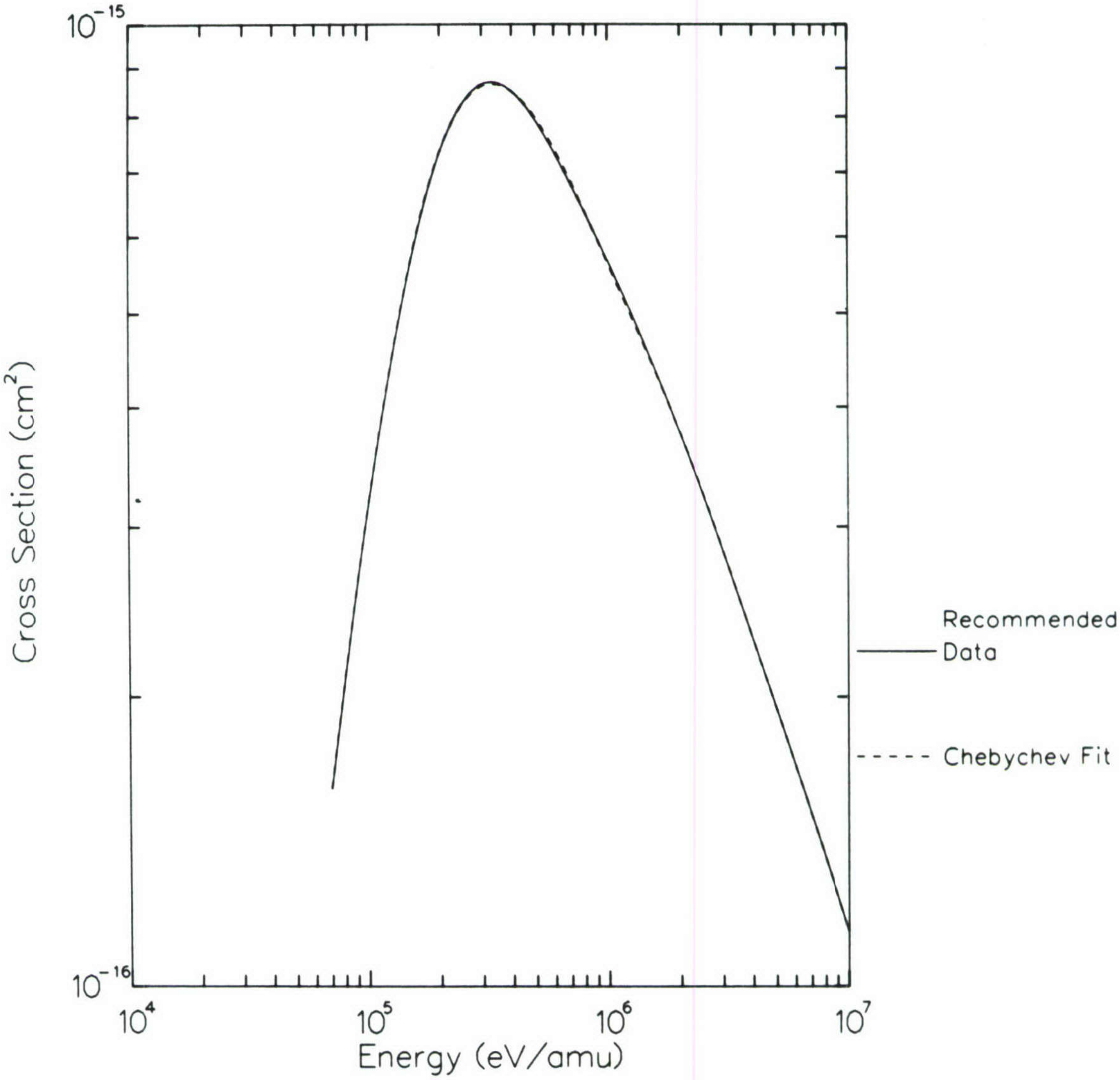
Chebychev Fitting Parameters for Cross Sections

C1	C2	C3	C4	C5	C6	C7	C8	C9
7.739E-16	-1.379E-16	-2.716E-16	1.648E-16	3.898E-18	-5.046E-17	2.907E-17	9.809E-19	-1.177E-17

The fit represents the above cross sections with an rms deviation of 0.6%.
The maximum deviation is 1.3% at 7.0E+05 eV/amu.
See appendix for Chebychev fit details.

$C^{6+} + He \rightarrow C^{6+} + He^{+} + e^{-}$

Cross Section vs. Energy



Ionization Rate Coefficients for
$He + C^{6+} \rightarrow C^{6+} + He^{+} + e^{-}$

Beam - Maxwellian Rate Coefficients (cm^3/s)

C^{6+} Temp. (eV)	He Energy (eV/amu) 70000.	80000.	90000.	100000.	200000.	400000.	500000.
1.0E+00	2.93E-08*	8.25E-08	1.07E-07	1.36E-07	4.63E-07	7.47E-07	7.86E-07
2.0E+00	2.94E-08**	8.24E-08	1.09E-07	1.39E-07	4.57E-07	7.47E-07	7.86E-07
4.0E+00	2.94E-08**	8.24E-08	1.09E-07	1.39E-07	4.57E-07	7.47E-07	7.86E-07
7.0E+00	2.95E-08**	8.24E-08	1.09E-07	1.39E-07	4.57E-07	7.47E-07	7.86E-07
1.0E+01	2.96E-08*	8.24E-08	1.09E-07	1.39E-07	4.57E-07	7.47E-07	7.86E-07
2.0E+01	2.97E-08*	8.24E-08	1.09E-07	1.39E-07	4.57E-07	7.47E-07	7.86E-07
4.0E+01	2.99E-08*	8.24E-08	1.09E-07	1.39E-07	4.56E-07	7.47E-07	7.86E-07
7.0E+01	3.02E-08*	8.25E-08	1.09E-07	1.39E-07	4.56E-07	7.47E-07	7.86E-07
1.0E+02	3.04E-08*	8.25E-08	1.09E-07	1.39E-07	4.56E-07	7.47E-07	7.86E-07
2.0E+02	3.09E-08*	8.25E-08	1.10E-07	1.39E-07	4.56E-07	7.47E-07	7.86E-07
4.0E+02	3.16E-08*	8.26E-08	1.10E-07	1.39E-07	4.56E-07	7.47E-07	7.86E-07
7.0E+02	3.24E-08*	8.28E-08	1.10E-07	1.39E-07	4.56E-07	7.47E-07	7.86E-07
1.0E+03	3.31E-08*	8.28E-08	1.10E-07	1.39E-07	4.56E-07	7.47E-07	7.86E-07
2.0E+03	3.48E-08*	8.23E-08	1.10E-07	1.40E-07	4.56E-07	7.47E-07	7.85E-07
4.0E+03	3.75E-08*	8.08E-08	1.11E-07	1.41E-07	4.57E-07	7.47E-07	7.85E-07
7.0E+03	4.06E-08*	7.97E-08	1.12E-07	1.42E-07	4.57E-07	7.47E-07	7.85E-07
1.0E+04	4.33E-08*	7.98E-08*	1.13E-07	1.44E-07	4.57E-07	7.46E-07	7.83E-07
2.0E+04	5.08E-08*	8.30E-08*	1.16E-07	1.48E-07	4.58E-07	7.46E-07	7.84E-07

Accuracy: * - Possible Error Greater Than 10%
** - Possible Error Greater Than 100%

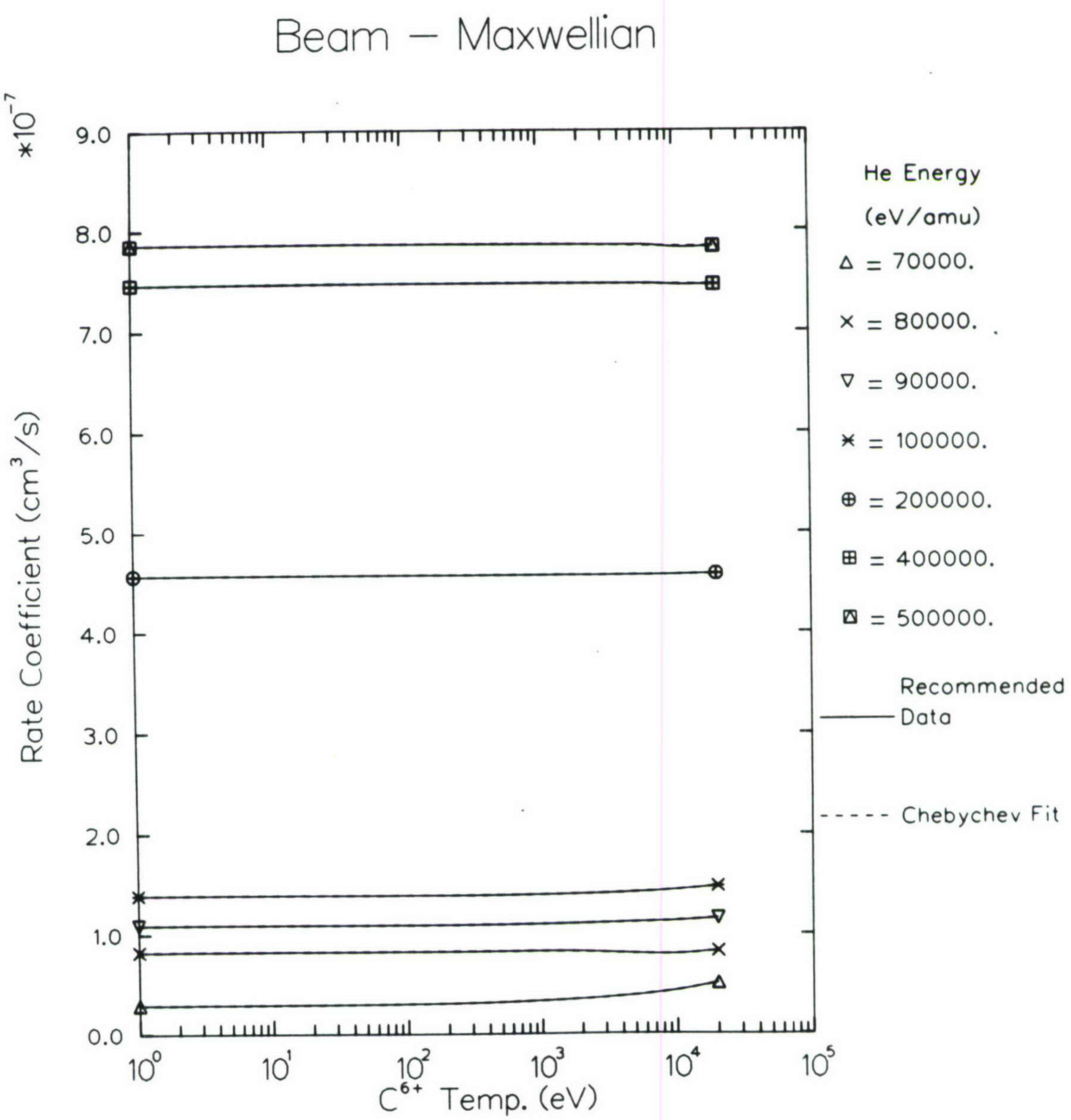
Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

Chebychev Fitting Parameters for Rate Coefficients

He Energy (eV/amu)	C1	C2	C3	C4	C5	C6	C7
70000.	6.916E-08	8.447E-09	4.643E-09	2.008E-09	7.423E-10	2.450E-10	7.219E-11
80000.	1.640E-07	-6.670E-10	-3.651E-10	1.609E-10	5.936E-10	6.483E-10	4.934E-10
90000.	2.209E-07	2.844E-09	9.707E-10	1.204E-09	-9.508E-11	3.707E-10	-1.634E-10
100000.	2.806E-07	3.604E-09	1.677E-09	1.607E-09	1.773E-10	4.224E-10	-1.605E-10
200000.	9.147E-07	-8.656E-10	1.504E-09	-7.703E-10	9.676E-10	-5.877E-10	4.979E-10
400000.	1.493E-06	-1.948E-10	-3.080E-10	-2.283E-10	-9.192E-11	7.524E-12	7.481E-11
500000.	1.570E-06	-8.801E-10	-6.400E-10	-2.864E-10	-2.739E-11	1.093E-10	2.054E-10

See appendix for Chebychev fit details.

$He + C^{6+} \rightarrow C^{6+} + He^{+} + e^{-}$



Ionization Cross Sections for
$O^+ + He \rightarrow O^+ + He^+ + e^-$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
4.0E+04	2.78E+08	4.45E-17
7.0E+04	3.68E+08	7.84E-17
1.0E+05	4.39E+08	8.34E-17
2.0E+05	6.21E+08	6.11E-17
4.0E+05	8.78E+08	3.95E-17
7.0E+05	1.16E+09	2.71E-17
1.0E+06	1.39E+09	2.08E-17
2.0E+06	1.96E+09	1.25E-17
4.0E+06	2.77E+09	7.04E-18
7.0E+06	3.65E+09	4.42E-18
1.0E+07	4.36E+09	3.23E-18

References: T.9, T.59, T.60

Accuracy: 50% for $E < 7x10^4$ eV/amu; 40% for $E \geq 7x10^4$ eV/amu

Note: In absence of experimental data for this reaction, the recommended cross section has been constructed using the semi-empirical scaling formula [T.60], with the fitting parameter determined from H^+ + He and Li^+ + He experimental data (see sect. 2.1.1). In the region around the maximum, the recommended cross section is consistent (within 30%) with the calculations in Ref. [T.9] and those based on three-state close-coupling theory [T.59].

For Chebychev fits of the above cross sections it is necessary to use the following parameters.
E_{min} = 4.0E+04 eV/amu, E_{max} = 1.0E+07 eV/amu

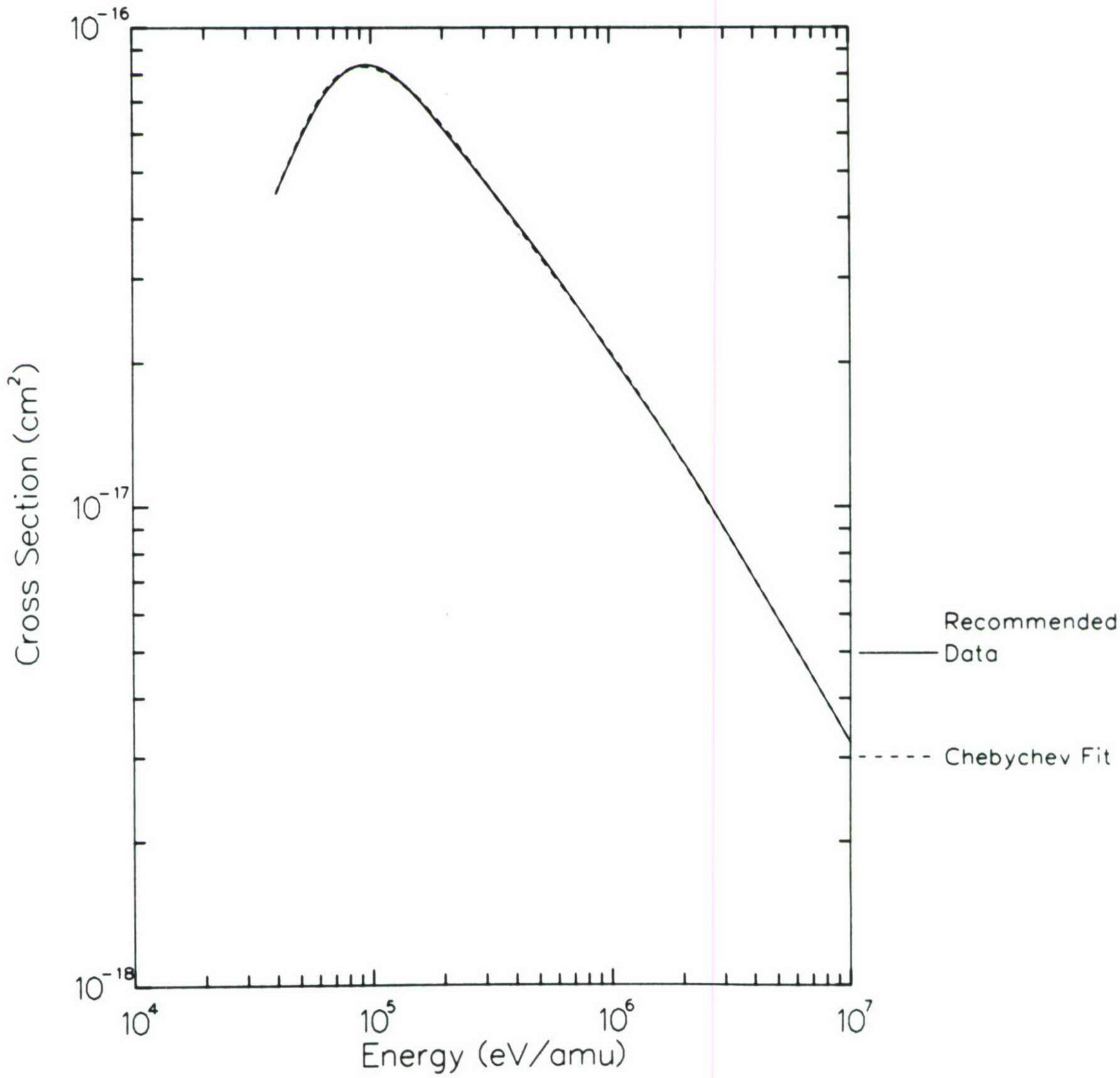
Chebychev Fitting Parameters for Cross Sections

C1	C2	C3	C4	C5	C6	C7	C8	C9
6.993E-17	-3.639E-17	-2.384E-18	1.327E-17	-9.215E-18	3.431E-18	-3.872E-20	-9.296E-19	5.199E-19

The fit represents the above cross sections with an rms deviation of 1.1%.
The maximum deviation is 2.0% at 2.0E+05 eV/amu.
See appendix for Chebychev fit details.

$O^{+} + He \rightarrow O^{+} + He^{+} + e^{-}$

Cross Section vs. Energy



Ionization Rate Coefficients for
$He + O^{+} \rightarrow O^{+} + He^{+} + e^{-}$

Beam - Maxwellian Rate Coefficients (cm^3/s)

O^{+} Temp. (eV)	He Energy (eV/amu) 40000.	50000.	60000.	70000.	100000.	200000.	500000.
1.0E+00	6.20E-09*	1.86E-08	2.42E-08	2.88E-08	3.66E-08	3.80E-08	3.35E-08
2.0E+00	6.21E-09**	1.86E-08	2.42E-08	2.88E-08	3.66E-08	3.80E-08	3.35E-08
4.0E+00	6.23E-09**	1.86E-08	2.42E-08	2.88E-08	3.66E-08	3.80E-08	3.35E-08
7.0E+00	6.24E-09**	1.86E-08	2.42E-08	2.88E-08	3.66E-08	3.80E-08	3.35E-08
1.0E+01	6.25E-09*	1.86E-08	2.42E-08	2.88E-08	3.66E-08	3.80E-08	3.35E-08
2.0E+01	6.28E-09*	1.86E-08	2.42E-08	2.88E-08	3.66E-08	3.80E-08	3.35E-08
4.0E+01	6.32E-09*	1.86E-08	2.42E-08	2.88E-08	3.66E-08	3.80E-08	3.35E-08
7.0E+01	6.37E-09*	1.86E-08	2.42E-08	2.88E-08	3.66E-08	3.80E-08	3.35E-08
1.0E+02	6.40E-09*	1.86E-08	2.42E-08	2.88E-08	3.66E-08	3.80E-08	3.35E-08
2.0E+02	6.50E-09*	1.86E-08	2.42E-08	2.88E-08	3.66E-08	3.80E-08	3.35E-08
4.0E+02	6.63E-09*	1.86E-08	2.42E-08	2.88E-08	3.66E-08	3.80E-08	3.35E-08
7.0E+02	6.78E-09*	1.86E-08	2.42E-08	2.88E-08	3.66E-08	3.80E-08	3.35E-08
1.0E+03	6.91E-09*	1.86E-08	2.42E-08	2.88E-08	3.66E-08	3.80E-08	3.35E-08
2.0E+03	7.23E-09*	1.86E-08	2.42E-08	2.88E-08	3.66E-08	3.81E-08	3.35E-08
4.0E+03	7.69E-09*	1.85E-08	2.42E-08	2.88E-08	3.66E-08	3.81E-08	3.35E-08
7.0E+03	8.22E-09*	1.83E-08	2.42E-08	2.88E-08	3.65E-08	3.81E-08	3.35E-08
1.0E+04	8.66E-09*	1.81E-08	2.42E-08	2.87E-08	3.65E-08	3.82E-08	3.34E-08
2.0E+04	9.80E-09*	1.78E-08	2.41E-08	2.86E-08	3.63E-08	3.82E-08	3.35E-08

Accuracy: * - Possible Error Greater Than 10%
** - Possible Error Greater Than 100%

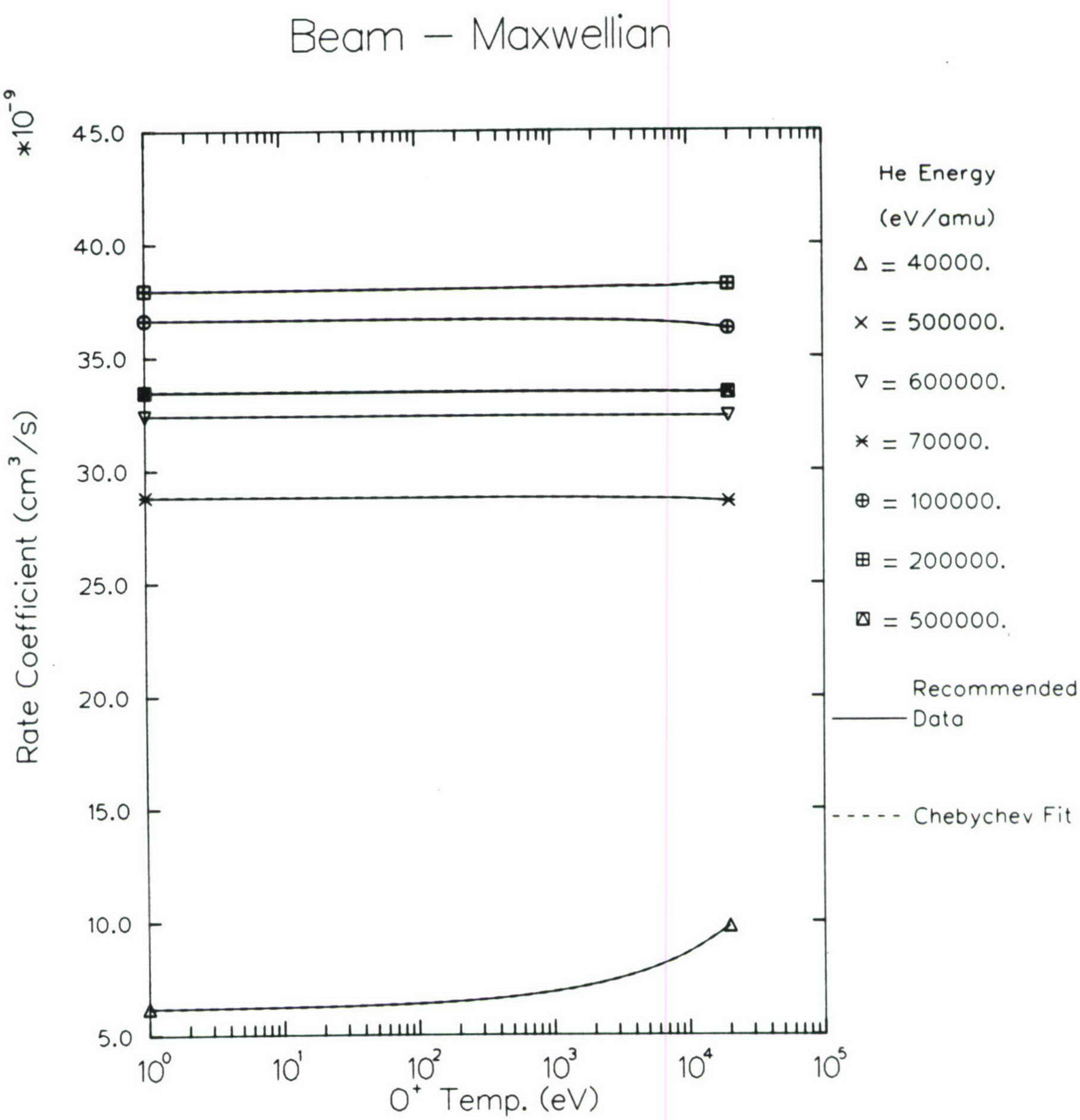
Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

Chebychev Fitting Parameters for Rate Coefficients

He Energy (eV/amu)	C1	C2	C3	C4	C5	C6	C7
40000.	1.425E-08	1.464E-09	7.716E-10	3.080E-10	9.988E-11	2.718E-11	6.021E-12
50000.	3.685E-08	-2.312E-10	-2.001E-10	-1.317E-10	-5.926E-11	-6.027E-12	2.524E-11
60000.	4.833E-08	4.046E-12	-8.295E-12	-1.963E-11	-2.162E-11	-1.633E-11	-9.492E-12
70000.	5.756E-08	-5.876E-11	-4.154E-11	-2.460E-11	-1.223E-11	-5.518E-12	-3.560E-12
100000.	7.314E-08	-1.182E-10	-9.249E-11	-5.777E-11	-2.867E-11	-1.130E-11	-3.446E-12
200000.	7.606E-08	1.085E-10	4.336E-11	9.790E-12	1.707E-12	1.865E-12	2.103E-12
500000.	6.692E-08	-5.930E-12	-4.368E-12	-1.804E-12	8.616E-14	1.088E-12	1.887E-12

See appendix for Chebychev fit details.

$He + O^{+} \rightarrow O^{+} + He^{+} + e^{-}$



Ionization Cross Sections for
$O^{2+} + He \rightarrow O^{2+} + He^{+} + e^{-}$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
4.6E+04	2.98E+08	6.39E-17
7.0E+04	3.68E+08	1.60E-16
1.0E+05	4.39E+08	2.05E-16
2.0E+05	6.21E+08	1.91E-16
4.0E+05	8.78E+08	1.41E-16
7.0E+05	1.16E+09	1.03E-16
1.0E+06	1.39E+09	8.10E-17
2.0E+06	1.96E+09	4.83E-17
4.0E+06	2.77E+09	2.72E-17
7.0E+06	3.65E+09	1.71E-17
1.0E+07	4.36E+09	1.27E-17

References: T.9, T.59, T.60

Accuracy: 50% for $E < 7\times10^{4}$ eV/amu; 30% for $E \geq 7\times10^{4}$ eV/amu

Note: There are no experimental data for this reaction. The recommended cross section has been constructed using the semi-empirical scaling formula [T.60], with the fitting parameters determined from experimental data on He^{2+} + He and Li^{2+} + He (see sect. 2.1.1). In the region near the maximum, this cross section is consistent (to within 20%) with the calculations of Ref. [T.9] and those based on the three-state close-coupling theory [T.59].

For Chebychev fits of the above cross sections it is necessary to use the following parameters.
E_{min} = 4.6E+04 eV/amu, E_{max} = 1.0E+07 eV/amu

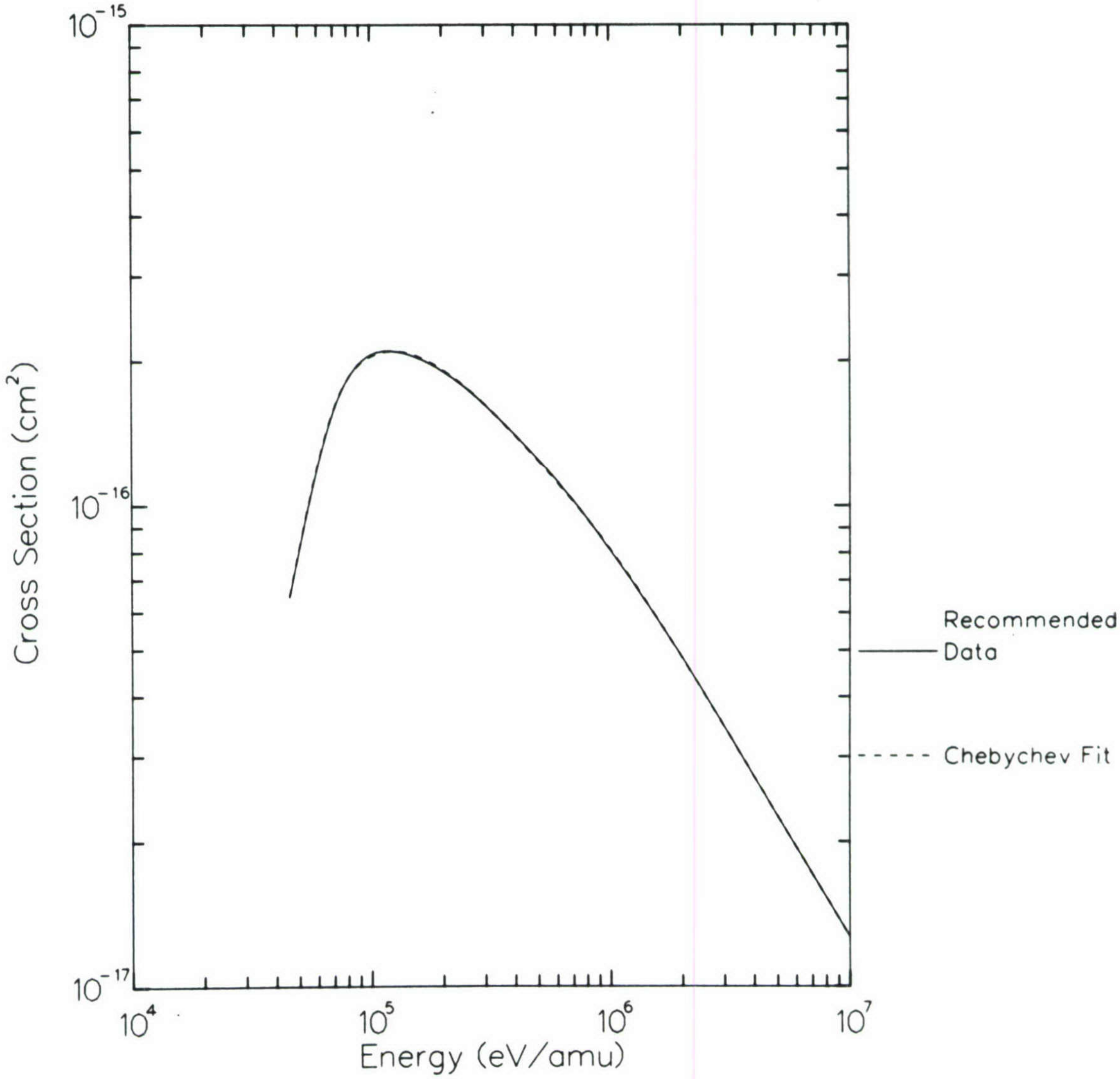
Chebychev Fitting Parameters for Cross Sections

C1	C2	C3	C4	C5	C6	C7	C8	C9
1.826E-16	-7.366E-17	-3.387E-17	4.511E-17	-2.124E-17	5.152E-18	8.157E-19	-2.186E-18	1.286E-18

The fit represents the above cross sections with an rms deviation of 0.6%.
The maximum deviation is 0.8% at 1.0E+06 eV/amu.
See appendix for Chebychev fit details.

$O^{2+} + He \rightarrow O^{2+} + He^{+} + e^{-}$

Cross Section vs. Energy



Ionization Rate Coefficients for
He + O^{2+} -> O^{2+} + He^{+} + e^{-}

Beam - Maxwellian Rate Coefficients (cm^3/s)

O^{2+} Temp. (eV)	He Energy (eV/amu) 50000.	60000.	70000.	80000.	100000.	200000.	500000.
1.0E+00	2.51E-08	4.20E-08	5.88E-08	7.30E-08	9.01E-08	1.19E-07	1.23E-07
2.0E+00	2.51E-08	4.20E-08	5.88E-08	7.30E-08	9.01E-08	1.19E-07	1.23E-07
4.0E+00	2.51E-08	4.20E-08	5.88E-08	7.30E-08	9.01E-08	1.19E-07	1.23E-07
7.0E+00	2.51E-08	4.20E-08	5.88E-08	7.30E-08	9.01E-08	1.19E-07	1.23E-07
1.0E+01	2.51E-08	4.20E-08	5.88E-08	7.30E-08	9.01E-08	1.19E-07	1.23E-07
2.0E+01	2.51E-08	4.20E-08	5.88E-08	7.30E-08	9.01E-08	1.19E-07	1.23E-07
4.0E+01	2.51E-08	4.21E-08	5.88E-08	7.30E-08	9.01E-08	1.19E-07	1.23E-07
7.0E+01	2.52E-08	4.21E-08	5.88E-08	7.30E-08	9.01E-08	1.19E-07	1.23E-07
1.0E+02	2.52E-08	4.21E-08	5.88E-08	7.30E-08	9.02E-08	1.19E-07	1.23E-07
2.0E+02	2.52E-08	4.21E-08	5.88E-08	7.30E-08	9.02E-08	1.19E-07	1.23E-07
4.0E+02	2.51E-08	4.21E-08	5.88E-08	7.30E-08	9.03E-08	1.19E-07	1.23E-07
7.0E+02	2.49E-08	4.22E-08	5.88E-08	7.30E-08	9.03E-08	1.19E-07	1.23E-07
1.0E+03	2.45E-08	4.22E-08	5.88E-08	7.30E-08	9.03E-08	1.19E-07	1.23E-07
2.0E+03	2.37E-08	4.23E-08	5.89E-08	7.29E-08	9.04E-08	1.19E-07	1.23E-07
4.0E+03	2.31E-08*	4.26E-08	5.89E-08	7.27E-08	9.04E-08	1.19E-07	1.23E-07
7.0E+03	2.32E-08*	4.28E-08	5.90E-08	7.26E-08	9.01E-08	1.19E-07	1.23E-07
1.0E+04	2.37E-08*	4.29E-08	5.91E-08	7.24E-08	9.02E-08	1.19E-07	1.23E-07
2.0E+04	2.59E-08*	4.35E-08	5.92E-08	7.19E-08	8.96E-08	1.19E-07	1.23E-07

Accuracy: * - Possible Error Greater Than 10%
** - Possible Error Greater Than 100%

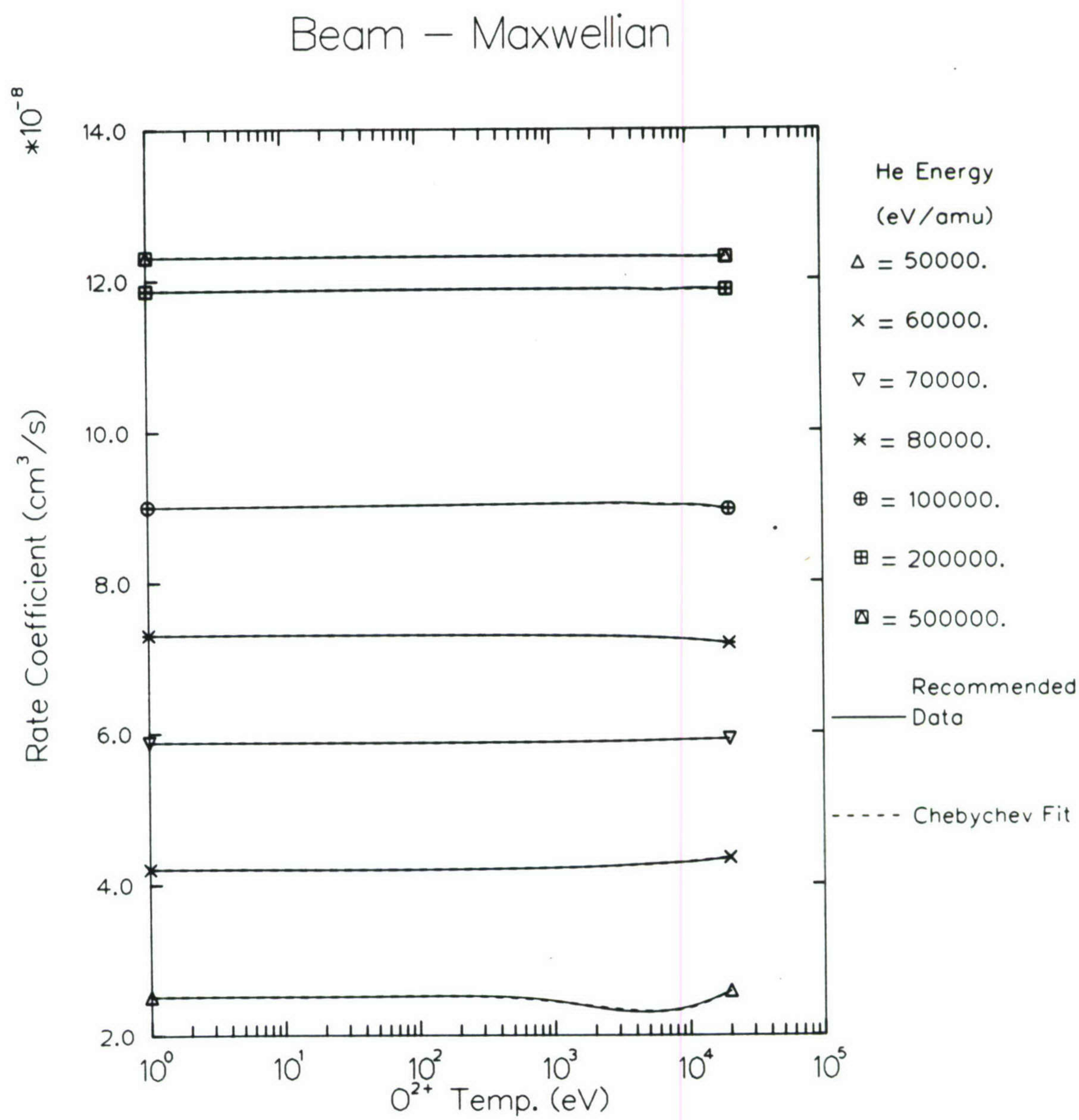
Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

Chebychev Fitting Parameters for Rate Coefficients

He Energy (eV/amu)	C1	C2	C3	C4	C5	C6	C7
50000.	4.955E-08	-4.988E-10	4.888E-11	5.083E-10	6.126E-10	3.941E-10	7.737E-11
60000.	8.475E-08	5.662E-10	3.539E-10	1.590E-10	4.600E-11	7.117E-12	7.667E-12
70000.	1.178E-07	1.506E-10	9.730E-11	4.226E-11	7.881E-12	-5.474E-12	-8.048E-12
80000.	1.456E-07	-4.111E-10	-2.842E-10	-1.559E-10	-6.757E-11	-2.261E-11	-5.915E-12
100000.	1.802E-07	-1.711E-11	-1.601E-10	-1.606E-10	-9.115E-11	-3.254E-11	-5.952E-12
200000.	2.373E-07	1.096E-11	-1.870E-11	-1.732E-11	-3.070E-12	6.587E-12	7.978E-12
500000.	2.461E-07	-3.145E-11	-2.297E-11	-1.065E-11	-1.587E-12	3.291E-12	6.792E-12

See appendix for Chebychev fit details.

$He + O^{2+} \rightarrow O^{2+} + He^{+} + e^{-}$



Ionization Cross Sections for
$O^{3+} + He \rightarrow O^{3+} + He^{+} + e^{-}$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
5.0E+04	3.11E+08	6.37E-17
7.0E+04	3.68E+08	1.55E-16
1.0E+05	4.39E+08	2.73E-16
2.0E+05	6.21E+08	3.53E-16
4.0E+05	8.78E+08	2.92E-16
7.0E+05	1.16E+09	2.21E-16
1.0E+06	1.39E+09	1.78E-16
2.0E+06	1.96E+09	1.09E-16
4.0E+06	2.77E+09	6.25E-17
7.0E+06	3.65E+09	3.96E-17
1.0E+07	4.36E+09	2.90E-17

References: E.67, E.69, T.9, T.59, T.60

Accuracy: 40% for $E < 1\times10^5$ eV/amu; 30% for $E \geq 1\times10^5$ eV/amu

Note: In absence of experimental data for this reaction, the recommended cross section has been constructed using the semi-empirical scaling formula [T.60] with the fitting parameters determined from Li^{3+} + He experimental data (see sect. 2.1.1). In the region $1.2\times10^5 \leq E(\text{eV/amu}) \leq 1\times10^6$, this cross section coincides with three-state close-coupling theory [T.59], and is consistent (to within 30%) with classical-trajectory Monte Carlo calculations [T.9] at $E = 1\times10^5$ eV/amu.

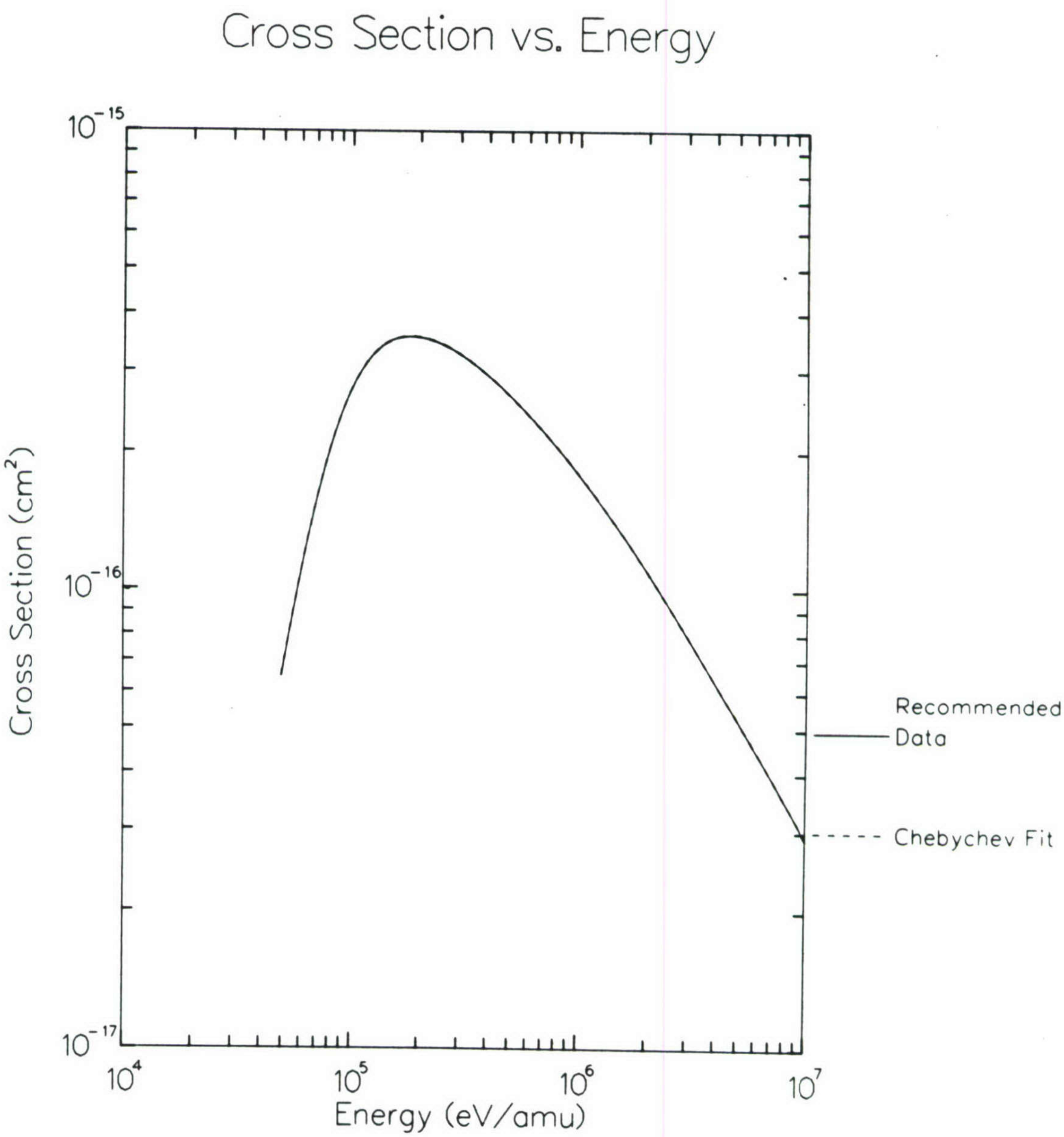
For Chebychev fits of the above cross sections it is necessary to use the following parameters.
E_{min} = 5.0E+04 eV/amu, E_{max} = 1.0E+07 eV/amu

Chebychev Fitting Parameters for Cross Sections

C1	C2	C3	C4	C5	C6	C7	C8	C9
3.027E-16	-8.564E-17	-9.766E-17	8.344E-17	-2.104E-17	-8.032E-18	1.116E-17	-7.120E-18	2.557E-18

The fit represents the above cross sections with an rms deviation of 0.1%.
The maximum deviation is 0.2% at 1.0E+06 eV/amu.
See appendix for Chebychev fit details.

$$O^{3+} + He \rightarrow O^{3+} + He^{+} + e^{-}$$



Ionization Rate Coefficients for:
$He + O^{3+} \rightarrow O^{3+} + He^{+} + e^{-}$

Beam - Maxwellian Rate Coefficients (cm^3/s)

O^{3+} Temp. (eV)	He Energy (eV/amu) 50000.	60000.	70000.	80000.	100000.	200000.	500000.
1.0E+00	9.94E-09*	3.66E-08	5.70E-08	7.89E-08	1.20E-07	2.19E-07	2.60E-07
2.0E+00	9.97E-09**	3.66E-08	5.70E-08	7.88E-08	1.20E-07	2.19E-07	2.60E-07
4.0E+00	1.00E-08**	3.66E-08	5.70E-08	7.88E-08	1.20E-07	2.19E-07	2.60E-07
7.0E+00	1.00E-08**	3.66E-08	5.70E-08	7.88E-08	1.20E-07	2.19E-07	2.60E-07
1.0E+01	1.01E-08*	3.66E-08	5.70E-08	7.88E-08	1.20E-07	2.19E-07	2.60E-07
2.0E+01	1.01E-08*	3.66E-08	5.70E-08	7.88E-08	1.20E-07	2.19E-07	2.60E-07
4.0E+01	1.02E-08*	3.66E-08	5.70E-08	7.88E-08	1.20E-07	2.19E-07	2.60E-07
7.0E+01	1.03E-08*	3.66E-08	5.70E-08	7.88E-08	1.20E-07	2.19E-07	2.60E-07
1.0E+02	1.04E-08*	3.67E-08	5.70E-08	7.88E-08	1.20E-07	2.19E-07	2.60E-07
2.0E+02	1.07E-08*	3.67E-08	5.70E-08	7.88E-08	1.20E-07	2.19E-07	2.60E-07
4.0E+02	1.10E-08*	3.68E-08	5.71E-08	7.88E-08	1.20E-07	2.19E-07	2.60E-07
7.0E+02	1.14E-08*	3.68E-08	5.71E-08	7.89E-08	1.20E-07	2.19E-07	2.60E-07
1.0E+03	1.17E-08*	3.69E-08	5.72E-08	7.90E-08	1.20E-07	2.19E-07	2.60E-07
2.0E+03	1.25E-08*	3.72E-08	5.75E-08	7.91E-08	1.20E-07	2.19E-07	2.60E-07
4.0E+03	1.38E-08*	3.74E-08	5.80E-08	7.95E-08	1.20E-07	2.19E-07	2.60E-07
7.0E+03	1.53E-08*	3.77E-08	5.87E-08	8.00E-08	1.21E-07	2.19E-07	2.60E-07
1.0E+04	1.67E-08*	3.81E-08	5.94E-08	8.06E-08	1.21E-07	2.19E-07	2.60E-07
2.0E+04	2.04E-08*	4.02E-08	6.13E-08	8.23E-08	1.22E-07	2.19E-07	2.60E-07

Accuracy: * - Possible Error Greater Than 10%
** - Possible Error Greater Than 100%

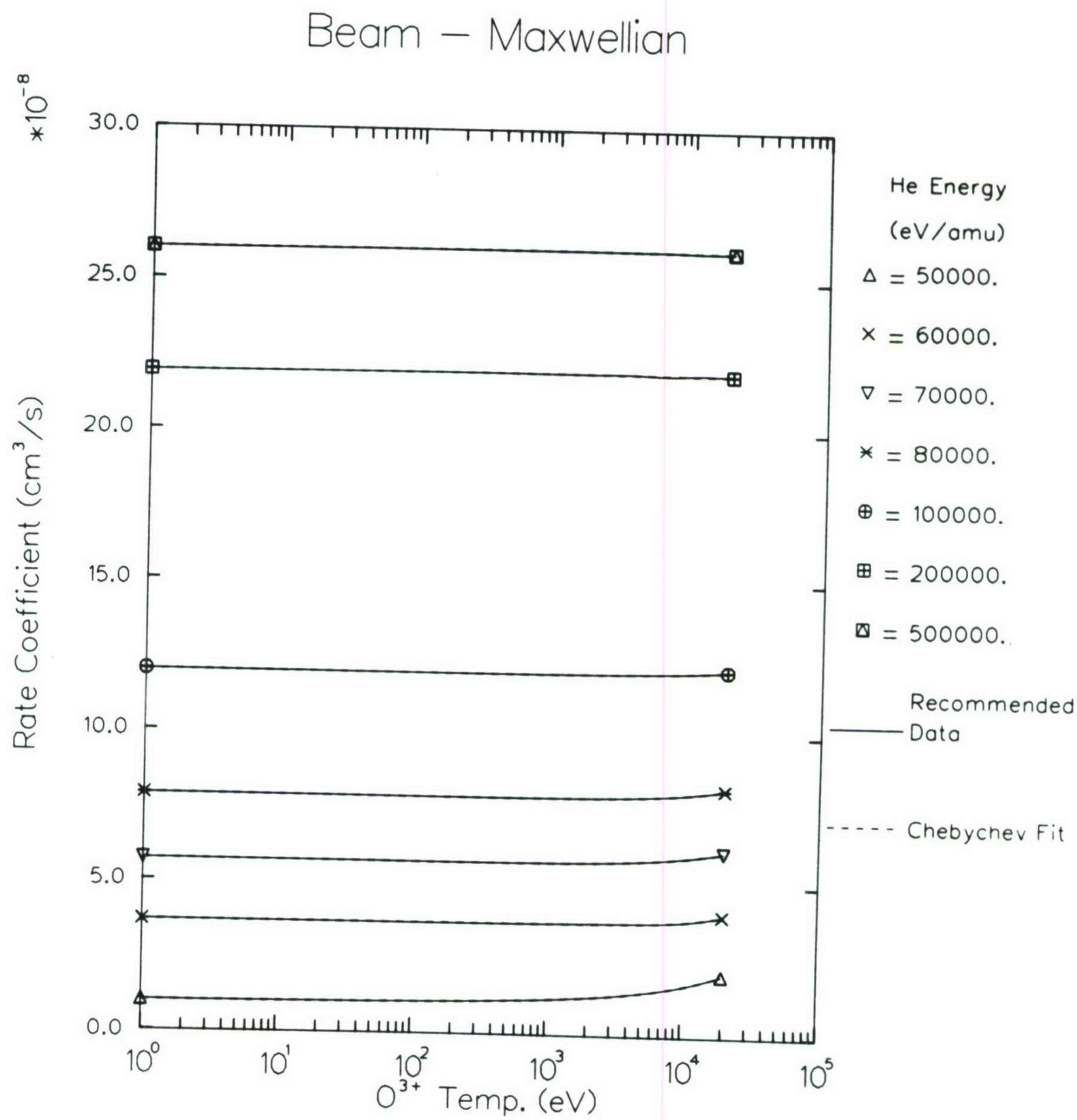
Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

Chebychev Fitting Parameters for Rate Coefficients

He Energy (eV/amu)	C1	C2	C3	C4	C5	C6	C7
50000.	2.495E-08	4.098E-09	2.292E-09	1.016E-09	3.853E-10	1.288E-10	3.698E-11
60000.	7.452E-08	1.145E-09	7.598E-10	4.580E-10	2.523E-10	1.590E-10	1.072E-10
70000.	1.156E-07	1.503E-09	1.052E-09	5.700E-10	2.528E-10	7.771E-11	1.937E-11
80000.	1.589E-07	1.152E-09	8.473E-10	4.662E-10	2.416E-10	8.021E-11	3.565E-11
100000.	2.406E-07	6.255E-10	3.894E-10	1.912E-10	8.695E-11	2.989E-11	1.184E-11
200000.	4.385E-07	-2.344E-11	-5.459E-11	-3.087E-11	4.936E-12	2.298E-11	2.253E-11
500000.	5.199E-07	-9.385E-11	-6.812E-11	-3.399E-11	-8.906E-12	4.764E-12	1.370E-11

See appendix for Chebychev fit details.

$He + O^{3+} \rightarrow O^{3+} + He^{+} + e^{-}$



Ionization Cross Sections for
$O^{4+} + He \rightarrow O^{4+} + He^{+} + e^{-}$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
6.0E+04	3.40E+08	2.36E-16
7.0E+04	3.68E+08	2.69E-16
1.0E+05	4.39E+08	3.56E-16
2.0E+05	6.21E+08	4.83E-16
4.0E+05	8.78E+08	4.53E-16
7.0E+05	1.16E+09	3.79E-16
1.0E+06	1.39E+09	3.20E-16
2.0E+06	1.96E+09	2.13E-16
4.0E+06	2.77E+09	1.23E-16
7.0E+06	3.65E+09	7.40E-17
1.0E+07	4.36E+09	5.06E-17

References: E.67, E.69, T.9, T.59, T.60

Accuracy: 40% for $E < 1.4\times10^5$ eV/amu; 20% for $1.4\times10^5 \leq E(\text{eV/amu}) \leq 6\times10^5$; 15% for $6\times10^5 \leq E(\text{eV/amu}) \leq 2\times10^6$; 20% for $E > 2\times10^6$ eV/amu

Note: In the energy region between 1.4×10^5 eV/amu and 6×10^5 eV/amu, the recommended cross section represents the experimental data [E.67], which agree with both three-state close-coupling theory [T.59] and the semi-empirical scaling formula (see sect. 2.1.1). These two theoretical sources have been used to construct the cross section outside this region.

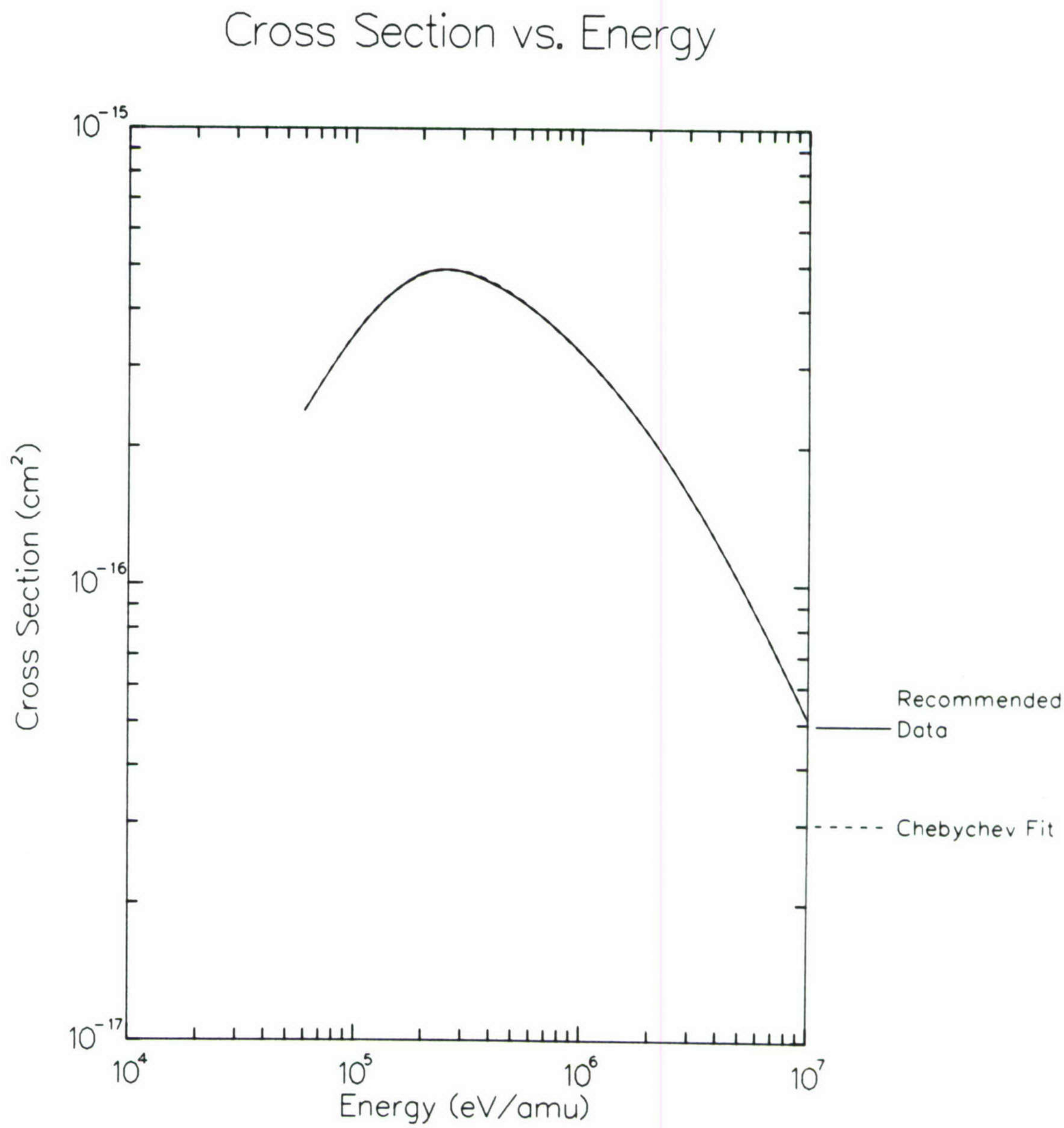
For Chebychev fits of the above cross sections it is necessary to use the following parameters.
E_{min} = 6.0E+04 eV/amu, E_{max} = 1.0E+07 eV/amu

Chebychev Fitting Parameters for Cross Sections

C1	C2	C3	C4	C5	C6	C7	C8	C9
5.152E-16	-1.536E-16	-1.168E-16	7.499E-17	-4.055E-18	-1.182E-17	8.141E-18	-2.512E-18	-1.352E-18

The fit represents the above cross sections with an rms deviation of 0.6%.
The maximum deviation is 1.3% at 4.0E+05 eV/amu.
See appendix for Chebychev fit details.

$O^{4+} + He \rightarrow O^{4+} + He^{+} + e^{-}$



Ionization Rate Coefficients for
$He + O^{4+} \rightarrow O^{4+} + He^{+} + e^{-}$

Beam - Maxwellian Rate Coefficients (cm^3/s)

O^{4+} Temp. (eV)	He Energy (eV/amu) 60000.	70000.	80000.	90000.	100000.	200000.	500000.
1.0E+00	4.02E-08*	9.56E-08	1.15E-07	1.36E-07	1.54E-07	2.98E-07	4.19E-07
2.0E+00	4.03E-08**	9.88E-08	1.18E-07	1.37E-07	1.56E-07	3.00E-07	4.19E-07
4.0E+00	4.03E-08**	9.89E-08	1.18E-07	1.37E-07	1.56E-07	3.00E-07	4.19E-07
7.0E+00	4.04E-08**	9.89E-08	1.18E-07	1.37E-07	1.56E-07	3.00E-07	4.19E-07
1.0E+01	4.04E-08**	9.89E-08	1.18E-07	1.37E-07	1.56E-07	3.00E-07	4.19E-07
2.0E+01	4.05E-08*	9.89E-08	1.18E-07	1.37E-07	1.56E-07	3.00E-07	4.19E-07
4.0E+01	4.07E-08*	9.89E-08	1.18E-07	1.37E-07	1.56E-07	3.00E-07	4.19E-07
7.0E+01	4.09E-08*	9.89E-08	1.18E-07	1.37E-07	1.56E-07	3.00E-07	4.19E-07
1.0E+02	4.10E-08*	9.89E-08	1.18E-07	1.37E-07	1.56E-07	3.00E-07	4.19E-07
2.0E+02	4.14E-08*	9.89E-08	1.18E-07	1.37E-07	1.56E-07	3.00E-07	4.19E-07
4.0E+02	4.19E-08*	9.89E-08	1.18E-07	1.37E-07	1.56E-07	3.00E-07	4.19E-07
7.0E+02	4.25E-08*	9.90E-08	1.18E-07	1.37E-07	1.56E-07	3.00E-07	4.19E-07
1.0E+03	4.30E-08*	9.90E-08	1.18E-07	1.37E-07	1.56E-07	3.00E-07	4.19E-07
2.0E+03	4.42E-08*	9.88E-08	1.18E-07	1.37E-07	1.56E-07	3.00E-07	4.19E-07
4.0E+03	4.60E-08*	9.69E-08	1.19E-07	1.38E-07	1.57E-07	3.00E-07	4.19E-07
7.0E+03	4.81E-08*	9.40E-08	1.19E-07	1.38E-07	1.57E-07	2.99E-07	4.19E-07
1.0E+04	4.98E-08*	9.21E-08*	1.19E-07	1.39E-07	1.57E-07	3.00E-07	4.18E-07
2.0E+04	5.44E-08*	8.97E-08*	1.18E-07	1.39E-07	1.59E-07	3.00E-07	4.19E-07

Accuracy: * - Possible Error Greater Than 10%
** - Possible Error Greater Than 100%

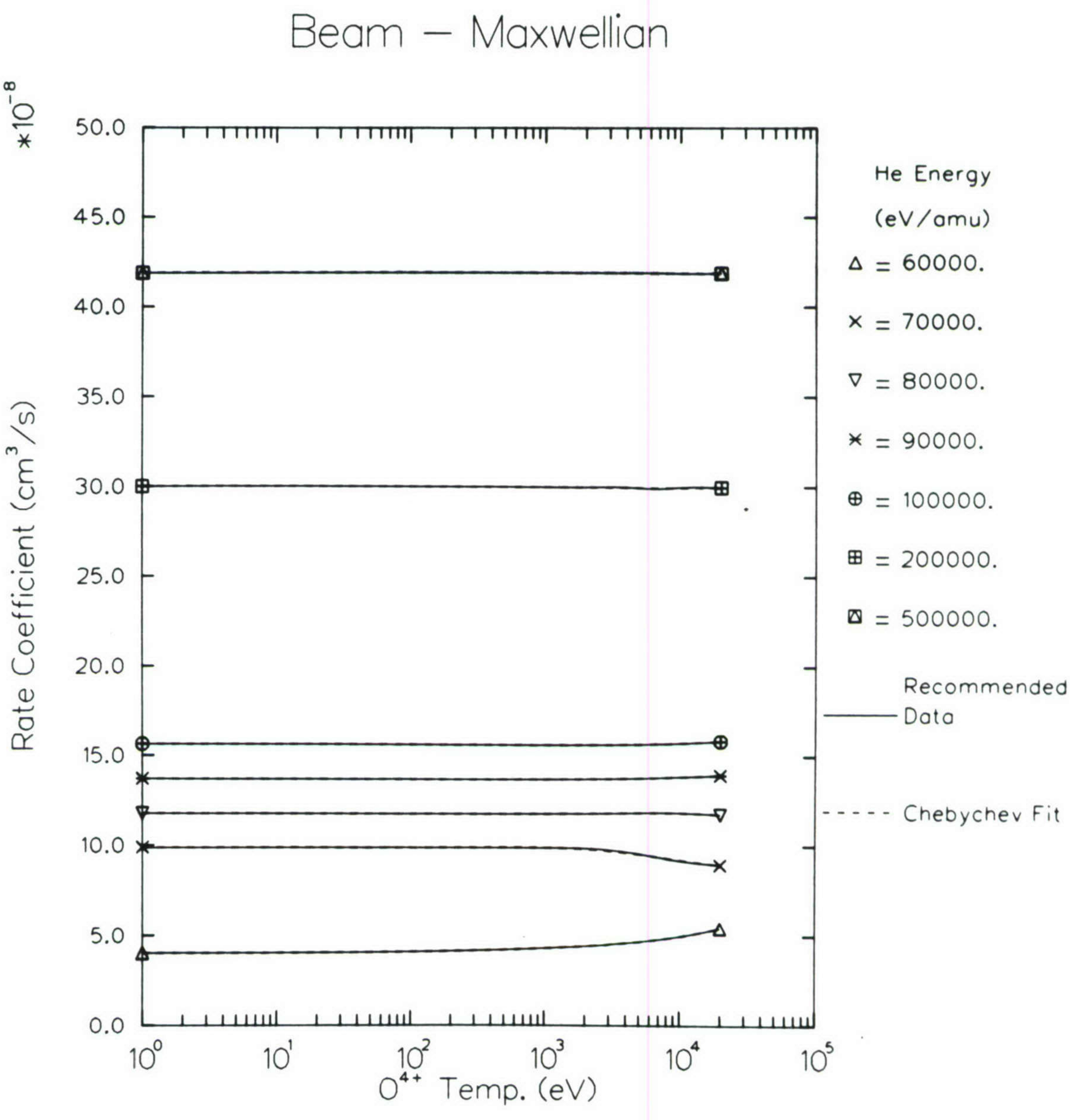
Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

Chebychev Fitting Parameters for Rate Coefficients

He Energy (eV/amu)	C1	C2	C3	C4	C5	C6	C7
60000.	8.768E-08	5.727E-09	3.029E-09	1.226E-09	4.134E-10	1.229E-10	3.326E-11
70000.	1.932E-07	-2.752E-09	-3.231E-09	-8.906E-10	-8.531E-10	4.962E-10	1.362E-10
80000.	2.354E-07	9.156E-10	-5.121E-10	3.677E-10	-6.321E-10	1.399E-10	-3.424E-10
90000.	2.750E-07	1.039E-09	5.232E-10	3.896E-10	2.721E-11	5.731E-11	-6.075E-11
100000.	3.131E-07	1.056E-09	1.909E-10	6.531E-10	-8.438E-11	2.622E-10	-1.276E-10
200000.	5.994E-07	2.073E-10	-4.327E-10	3.377E-10	-1.995E-10	2.697E-10	-1.030E-10
500000.	8.373E-07	-8.349E-11	-6.136E-11	-2.587E-11	2.523E-13	1.411E-11	2.497E-11

See appendix for Chebychev fit details.

$He + O^{4+} \rightarrow O^{4+} + He^{+} + e^{-}$



Ionization Cross Sections for
$O^{5+} + He \rightarrow O^{5+} + He^{+} + e^{-}$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
5.5E+04	3.26E+08	1.23E-16
7.0E+04	3.68E+08	1.88E-16
1.0E+05	4.39E+08	3.15E-16
2.0E+05	6.21E+08	5.60E-16
3.0E+05	7.61E+08	6.08E-16
4.0E+05	8.78E+08	5.89E-16
7.0E+05	1.16E+09	4.98E-16
1.0E+06	1.39E+09	4.28E-16
2.0E+06	1.96E+09	2.93E-16
4.0E+06	2.77E+09	1.77E-16
7.0E+06	3.65E+09	1.12E-16
1.0E+07	4.36E+09	8.16E-17

References: E.67, E.69, T.9, T.59, T.60

Accuracy: 40% for $E < 1x10^5$ eV/amu; 20% for $1x10^5 \leq E(eV/amu) < 4x10^6$; 15% for $E \geq 4x10^6$ eV/amu

Note: In the region above $4x10^5$ eV/amu, the recommended cross section represents the experimental data [E.67], [E.69], which are in agreement with the three-state close-coupling theory [T.59] (up to $3x10^6$ eV/amu) and with the semi-empiricial formula [T.60]. Below $4x10^5$ eV/amu, the cross section has been constructed on the basis of theoretical [T.59] and semi-empirical [T.60] predictions, (see sect. 2.1.1).

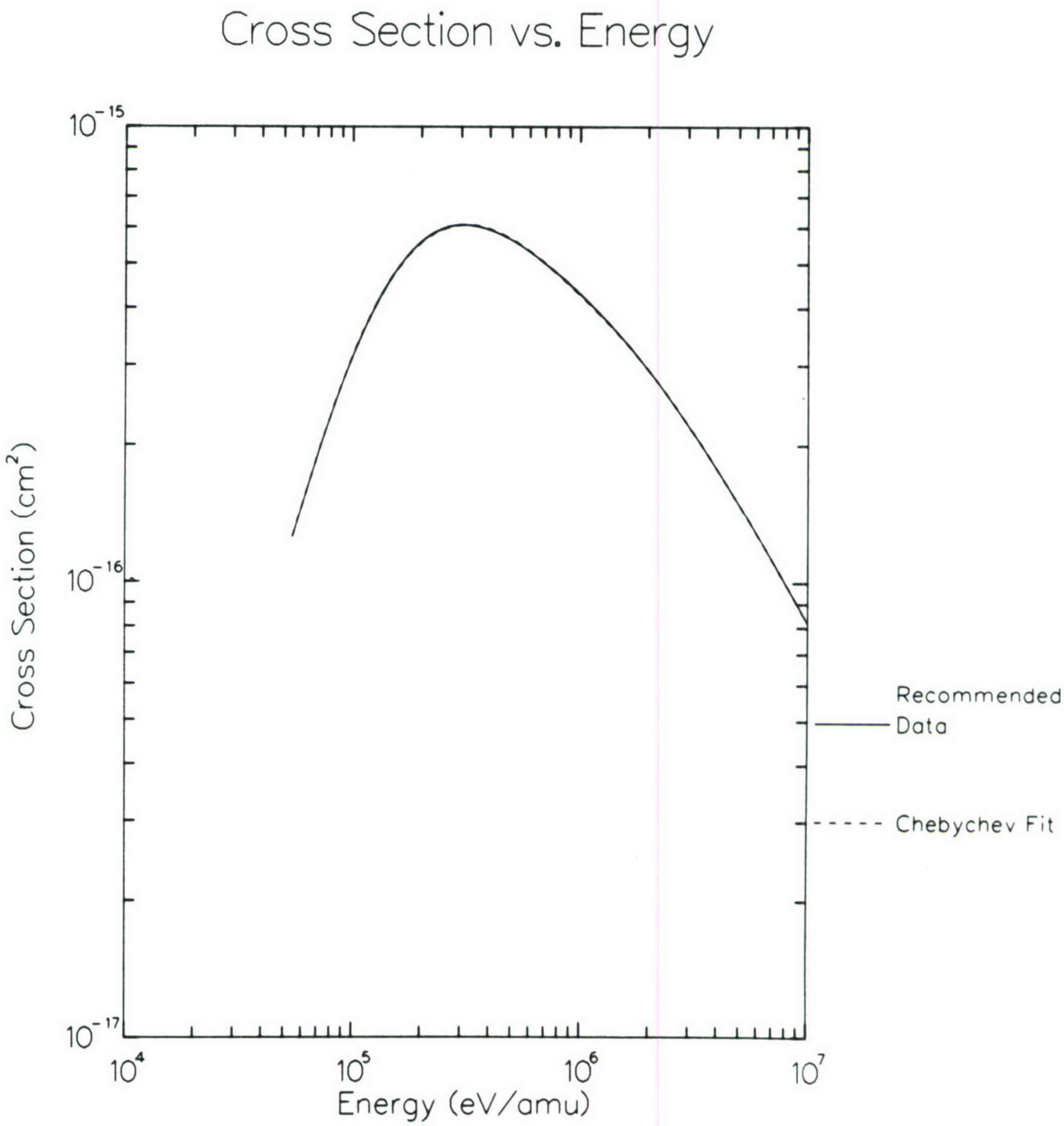
For Chebychev fits of the above cross sections it is necessary to use the following parameters.
E_{min} = 5.5E+04 eV/amu, E_{max} = 1.0E+07 eV/amu

Chebychev Fitting Parameters for Cross Sections

C1	C2	C3	C4	C5	C6	C7	C8	C9
5.744E-16	-9.212E-17	-2.060E-16	9.937E-17	1.332E-17	-2.923E-17	1.342E-17	1.259E-18	-5.662E-18

The fit represents the above cross sections with an rms deviation of 0.4%.
The maximum deviation is 0.8% at 4.0E+05 eV/amu.
See appendix for Chebychev fit details.

$O^{5+} + He \rightarrow O^{5+} + He^{+} + e^{-}$



Ionization Rate Coefficients for
$He + O^{5+} \rightarrow O^{5+} + He^{+} + e^{-}$

Beam - Maxwellian Rate Coefficients (cm^3/s)

O^{5+} Temp. (eV)	He Energy (eV/amu) 60000.	70000.	80000.	90000.	100000.	200000.	500000.
1.0E+00	4.91E-08	6.90E-08	9.47E-08	1.08E-07	1.41E-07	3.88E-07	5.50E-07
2.0E+00	4.91E-08	6.91E-08	9.14E-08	1.14E-07	1.38E-07	3.51E-07	5.50E-07
4.0E+00	4.91E-08	6.91E-08	9.10E-08	1.14E-07	1.38E-07	3.48E-07	5.50E-07
7.0E+00	4.91E-08	6.91E-08	9.10E-08	1.14E-07	1.38E-07	3.48E-07	5.50E-07
1.0E+01	4.91E-08	6.91E-08	9.10E-08	1.14E-07	1.38E-07	3.48E-07	5.50E-07
2.0E+01	4.91E-08	6.91E-08	9.10E-08	1.14E-07	1.38E-07	3.48E-07	5.50E-07
4.0E+01	4.91E-08	6.91E-08	9.10E-08	1.14E-07	1.38E-07	3.48E-07	5.50E-07
7.0E+01	4.91E-08	6.91E-08	9.10E-08	1.14E-07	1.38E-07	3.48E-07	5.50E-07
1.0E+02	4.91E-08	6.91E-08	9.10E-08	1.14E-07	1.38E-07	3.48E-07	5.50E-07
2.0E+02	4.92E-08	6.91E-08	9.11E-08	1.14E-07	1.38E-07	3.48E-07	5.50E-07
4.0E+02	4.92E-08	6.92E-08	9.11E-08	1.14E-07	1.38E-07	3.48E-07	5.50E-07
7.0E+02	4.88E-08	6.93E-08	9.12E-08	1.14E-07	1.38E-07	3.48E-07	5.50E-07
1.0E+03	4.83E-08	6.94E-08	9.13E-08	1.15E-07	1.39E-07	3.48E-07	5.50E-07
2.0E+03	4.64E-08	6.97E-08	9.16E-08	1.15E-07	1.39E-07	3.48E-07	5.50E-07
4.0E+03	4.44E-08*	7.01E-08	9.21E-08	1.15E-07	1.39E-07	3.48E-07	5.50E-07
7.0E+03	4.35E-08*	7.04E-08	9.29E-08	1.16E-07	1.40E-07	3.48E-07	5.50E-07
1.0E+04	4.36E-08*	7.06E-08	9.37E-08	1.17E-07	1.41E-07	3.48E-07	5.50E-07
2.0E+04	4.57E-08*	7.16E-08	9.58E-08	1.19E-07	1.43E-07	3.48E-07	5.50E-07

Accuracy: * - Possible Error Greater Than 10%
** - Possible Error Greater Than 100%

Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

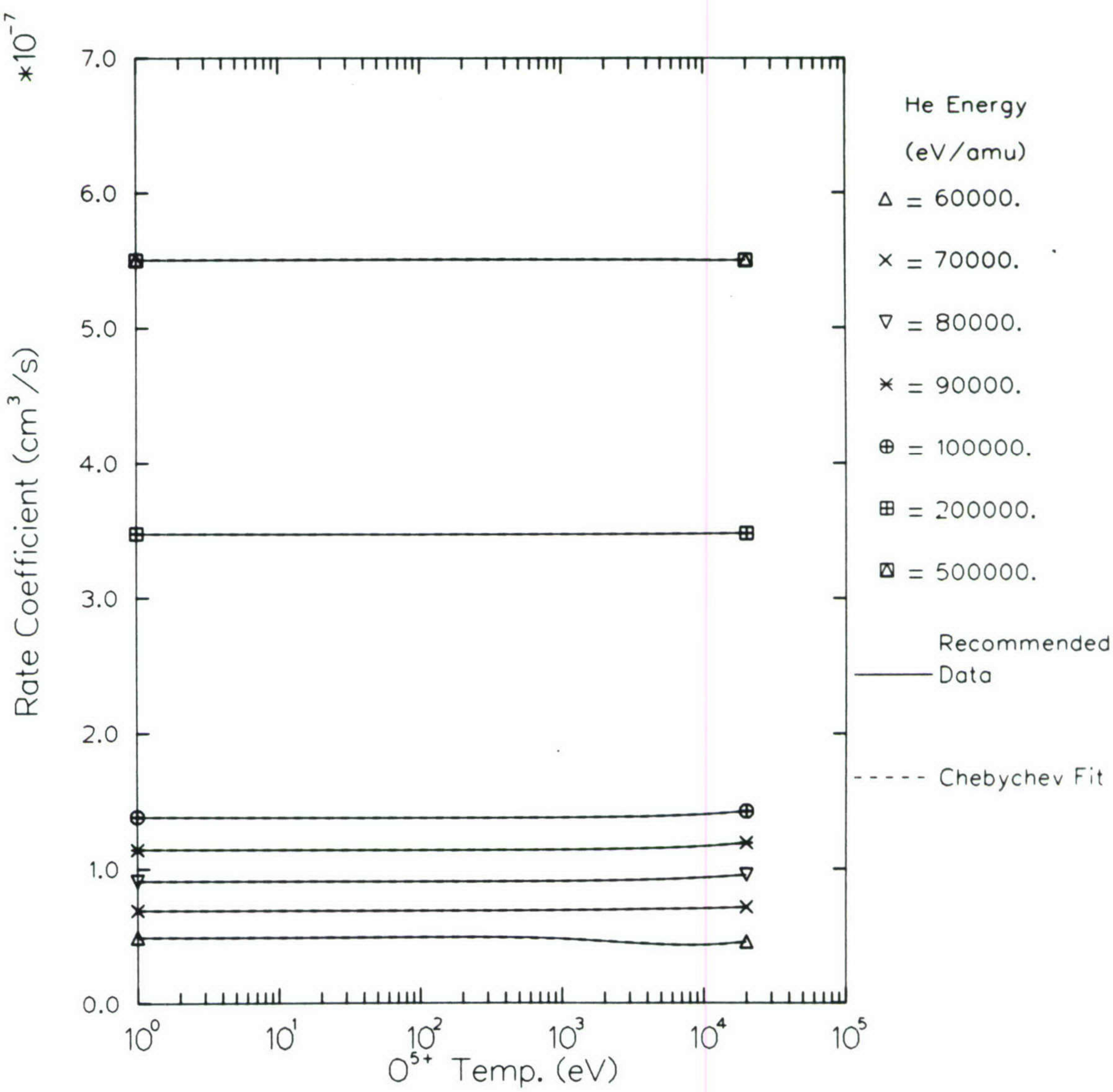
Chebychev Fitting Parameters for Rate Coefficients

He Energy (eV/amu)	C1	C2	C3	C4	C5	C6	C7
60000.	9.511E-08	-2.548E-09	-1.200E-09	1.600E-10	8.347E-10	7.454E-10	2.711E-10
70000.	1.393E-07	9.808E-10	5.703E-10	2.671E-10	5.220E-11	2.101E-11	1.302E-11
80000.	1.847E-07	8.309E-10	1.879E-09	1.051E-11	7.449E-10	-2.485E-10	2.358E-10
90000.	2.291E-07	3.017E-09	2.014E-11	1.764E-09	-5.187E-10	7.793E-10	-4.382E-10
100000.	2.788E-07	1.043E-09	1.483E-09	2.675E-10	6.168E-10	-1.131E-10	2.261E-10
200000.	7.047E-07	-8.527E-09	7.788E-09	-6.672E-09	5.146E-09	-3.740E-09	2.563E-09
500000.	1.100E-06	-1.716E-10	-1.249E-10	-6.013E-11	-1.251E-11	1.327E-11	3.096E-11

See appendix for Chebychev fit details.

$He + O^{5+} -> O^{5+} + He^{+} + e^{-}$

Beam – Maxwellian



Ionization Cross Sections for
$O^{6+} + He \rightarrow O^{6+} + He^{+} + e^{-}$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
7.0E+04	3.68E+08	1.58E-16
1.0E+05	4.39E+08	3.14E-16
2.0E+05	6.21E+08	6.59E-16
4.0E+05	8.78E+08	7.25E-16
7.0E+05	1.16E+09	6.39E-16
1.0E+06	1.39E+09	5.46E-16
2.0E+06	1.96E+09	3.76E-16
4.0E+06	2.77E+09	2.38E-16
7.0E+06	3.65E+09	1.56E-16
1.0E+07	4.36E+09	1.16E-16

References: E.67, E.69, T.9, T.59, T.60

Accuracy: 40% for $E < 2x10^5$ eV/amu; 20% for $2x10^5 \leq E(eV/amu) < 5x10^5$; 15% for $E \geq 5x10^5$ eV/amu

Note: For $E \geq 2x10^5$ eV/amu, the recommended cross section has been constructed using the experimental data, [E.67], [E.69], three-state close-coupling calculations [T.59] and the semi-empirical scaling (see sect. 2.1.1). For energies below $2x10^5$ eV/amu, the data from Refs. [T.59] and [T.9] have been used to determine the cross section.

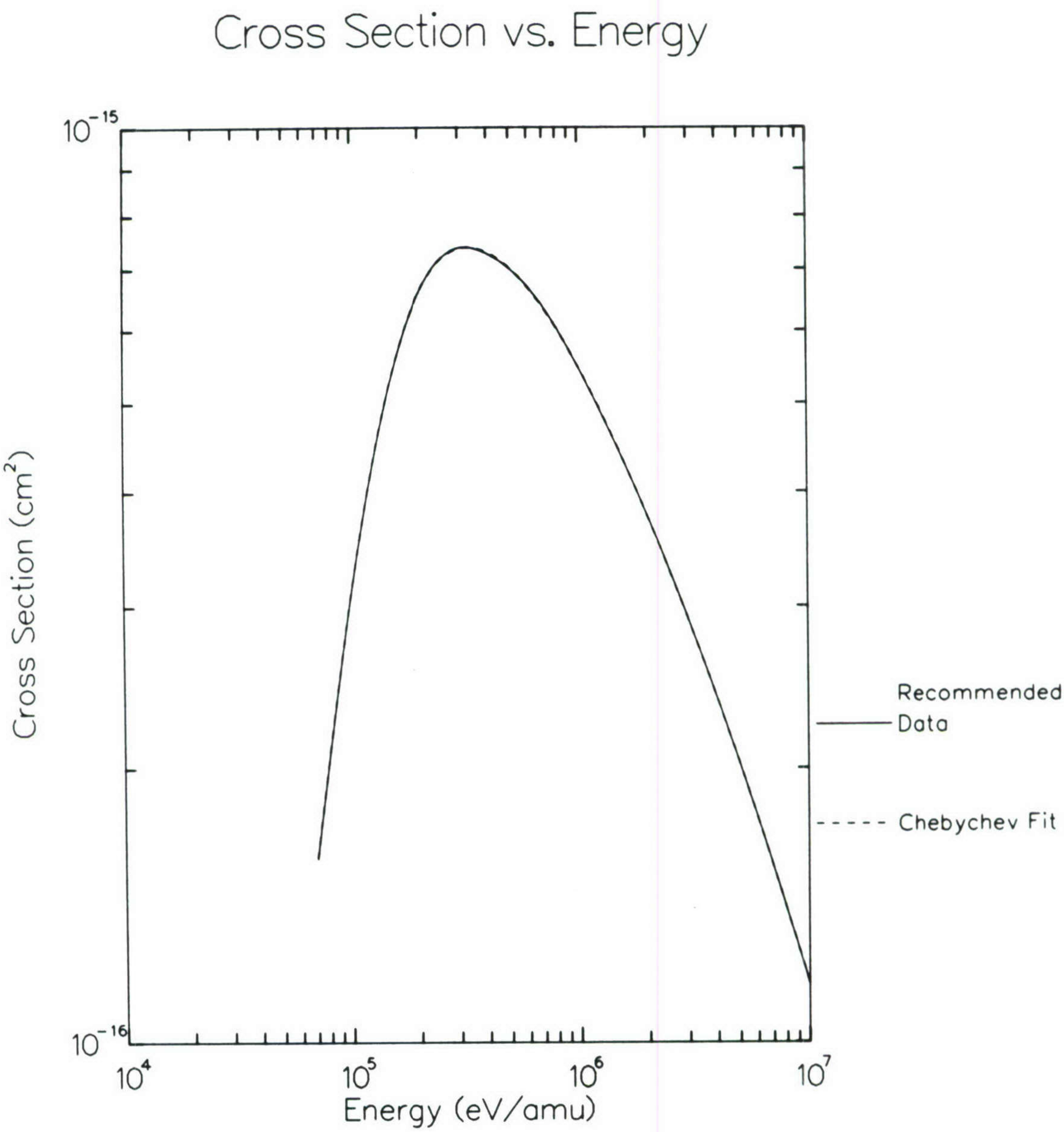
For Chebychev fits of the above cross sections it is necessary to use the following parameters.
E_{min} = 7.0E+04 eV/amu, E_{max} = 1.0E+07 eV/amu

Chebychev Fitting Parameters for Cross Sections

C1	C2	C3	C4	C5	C6	C7	C8	C9
7.292E-16	-1.178E-16	-2.439E-16	1.298E-16	-5.107E-19	-2.825E-17	1.597E-17	-4.667E-18	8.489E-19

The fit represents the above cross sections with an rms deviation of 0.3%.
The maximum deviation is 0.7% at 4.0E+05 eV/amu.
See appendix for Chebychev fit details.

$O^{6+} + He \rightarrow O^{6+} + He^{+} + e^{-}$



Ionization Rate Coefficients for
$He + O^{6+} \rightarrow O^{6+} + He^{+} + e^{-}$

Beam - Maxwellian Rate Coefficients (cm^3/s)

O^{6+} Temp. (eV)	He Energy (eV/amu) 70000.	80000.	90000.	100000.	200000.	400000.	500000.
1.0E+00	2.91E-08*	8.23E-08	1.09E-07	1.38E-07	4.09E-07	6.37E-07	6.86E-07
2.0E+00	2.92E-08**	8.23E-08	1.09E-07	1.38E-07	4.09E-07	6.37E-07	6.86E-07
4.0E+00	2.92E-08**	8.23E-08	1.09E-07	1.38E-07	4.09E-07	6.37E-07	6.86E-07
7.0E+00	2.93E-08**	8.23E-08	1.09E-07	1.38E-07	4.09E-07	6.37E-07	6.86E-07
1.0E+01	2.93E-08**	8.23E-08	1.09E-07	1.38E-07	4.09E-07	6.37E-07	6.86E-07
2.0E+01	2.95E-08*	8.23E-08	1.09E-07	1.38E-07	4.09E-07	6.37E-07	6.86E-07
4.0E+01	2.97E-08*	8.23E-08	1.09E-07	1.38E-07	4.09E-07	6.37E-07	6.86E-07
7.0E+01	2.99E-08*	8.23E-08	1.09E-07	1.38E-07	4.09E-07	6.37E-07	6.86E-07
1.0E+02	3.00E-08*	8.23E-08	1.09E-07	1.38E-07	4.09E-07	6.37E-07	6.86E-07
2.0E+02	3.05E-08*	8.23E-08	1.09E-07	1.38E-07	4.09E-07	6.37E-07	6.86E-07
4.0E+02	3.11E-08*	8.24E-08	1.09E-07	1.38E-07	4.10E-07	6.37E-07	6.86E-07
7.0E+02	3.18E-08*	8.25E-08	1.09E-07	1.38E-07	4.10E-07	6.37E-07	6.86E-07
1.0E+03	3.24E-08*	8.26E-08	1.10E-07	1.38E-07	4.10E-07	6.37E-07	6.86E-07
2.0E+03	3.39E-08*	8.25E-08	1.10E-07	1.39E-07	4.10E-07	6.37E-07	6.86E-07
4.0E+03	3.61E-08*	8.13E-08	1.11E-07	1.39E-07	4.10E-07	6.37E-07	6.86E-07
7.0E+03	3.87E-08*	7.99E-08	1.11E-07	1.40E-07	4.10E-07	6.37E-07	6.86E-07
1.0E+04	4.09E-08*	7.94E-08	1.12E-07	1.41E-07	4.10E-07	6.37E-07	6.86E-07
2.0E+04	4.70E-08*	8.06E-08*	1.13E-07	1.44E-07	4.11E-07	6.38E-07	6.86E-07

Accuracy: * - Possible Error Greater Than 10%
** - Possible Error Greater Than 100%

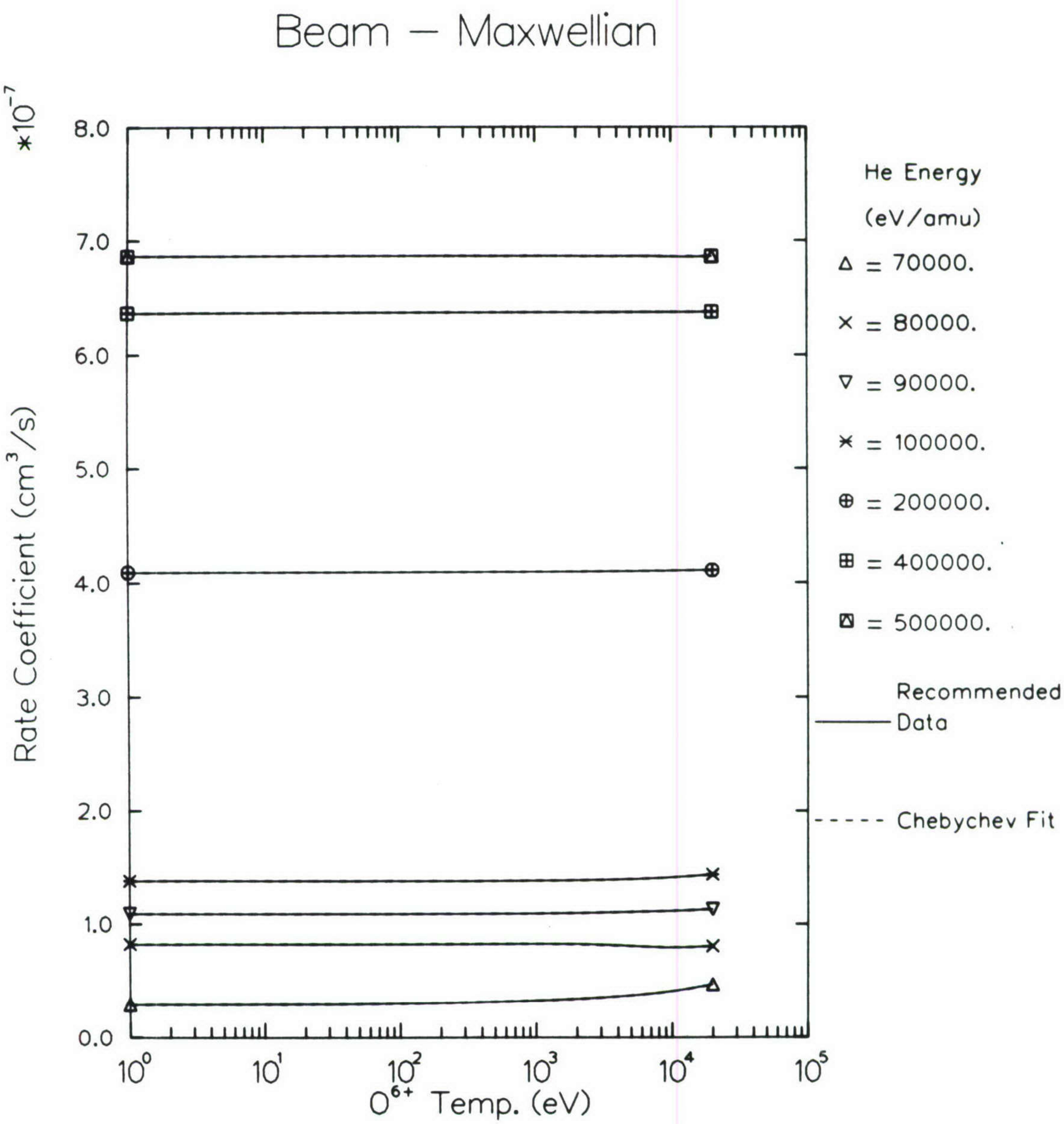
Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

Chebychev Fitting Parameters for Rate Coefficients

He Energy (eV/amu)	C1	C2	C3	C4	C5	C6	C7
70000.	6.715E-08	7.117E-09	3.863E-09	1.634E-09	5.857E-10	1.864E-10	5.306E-11
80000.	1.633E-07	-1.013E-09	-7.840E-10	-2.757E-10	1.668E-10	3.699E-10	3.768E-10
90000.	2.201E-07	1.580E-09	1.015E-09	4.645E-10	1.266E-10	-3.558E-12	-1.880E-11
100000.	2.782E-07	2.069E-09	1.447E-09	8.038E-10	3.518E-10	1.146E-10	1.855E-11
200000.	8.194E-07	6.156E-10	3.122E-10	1.415E-10	3.908E-11	2.025E-11	2.583E-13
400000.	1.274E-06	3.736E-10	1.322E-10	1.341E-11	-9.791E-12	-2.025E-12	9.290E-12
500000.	1.373E-06	-1.303E-10	-9.593E-11	-3.945E-11	2.150E-12	2.417E-11	4.177E-11

See appendix for Chebychev fit details.

$He + O^{6+} \rightarrow O^{6+} + He^{+} + e^{-}$



Ionization Cross Sections for
$O^{7+} + He \rightarrow O^{7+} + He^{+} + e^{-}$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
1.0E+05	4.39E+08	4.27E-16
2.0E+05	6.21E+08	7.90E-16
4.0E+05	8.78E+08	9.89E-16
7.0E+05	1.16E+09	8.31E-16
1.0E+06	1.39E+09	7.04E-16
2.0E+06	1.96E+09	4.83E-16
4.0E+06	2.77E+09	3.03E-16
7.0E+06	3.65E+09	2.01E-16
1.0E+07	4.36E+09	1.50E-16

References: E.67, E.69, T.9, T.59, T.60

Accuracy: 40% for E < $2x10^5$ eV/amu; 25% for $2x10^5 \leq$ E(eV/amu) $\leq 5x10^5$; 15% for E > $5x10^5$ eV/amu

Note: In the region above $5x10^5$ eV/amu the recommended cross section is based on experimental data [E.67], [E.69] and semi-empirical scaling (see sect. 2.1.1), while for E < $5x10^5$ eV/amu, the cross section has been constructed using the three-state close coupling theory [T.59], classical-trajectory Monte Carlo calculations [T.9] (for E = $1x10^5$ eV/amu), and the empirical scaling for the maximum cross section, (see sect. 2.1.1).

For Chebychev fits of the above cross sections it is necessary to use the following parameters.
E_{min} = 1.0E+05 eV/amu, E_{max} = 1.0E+07 eV/amu

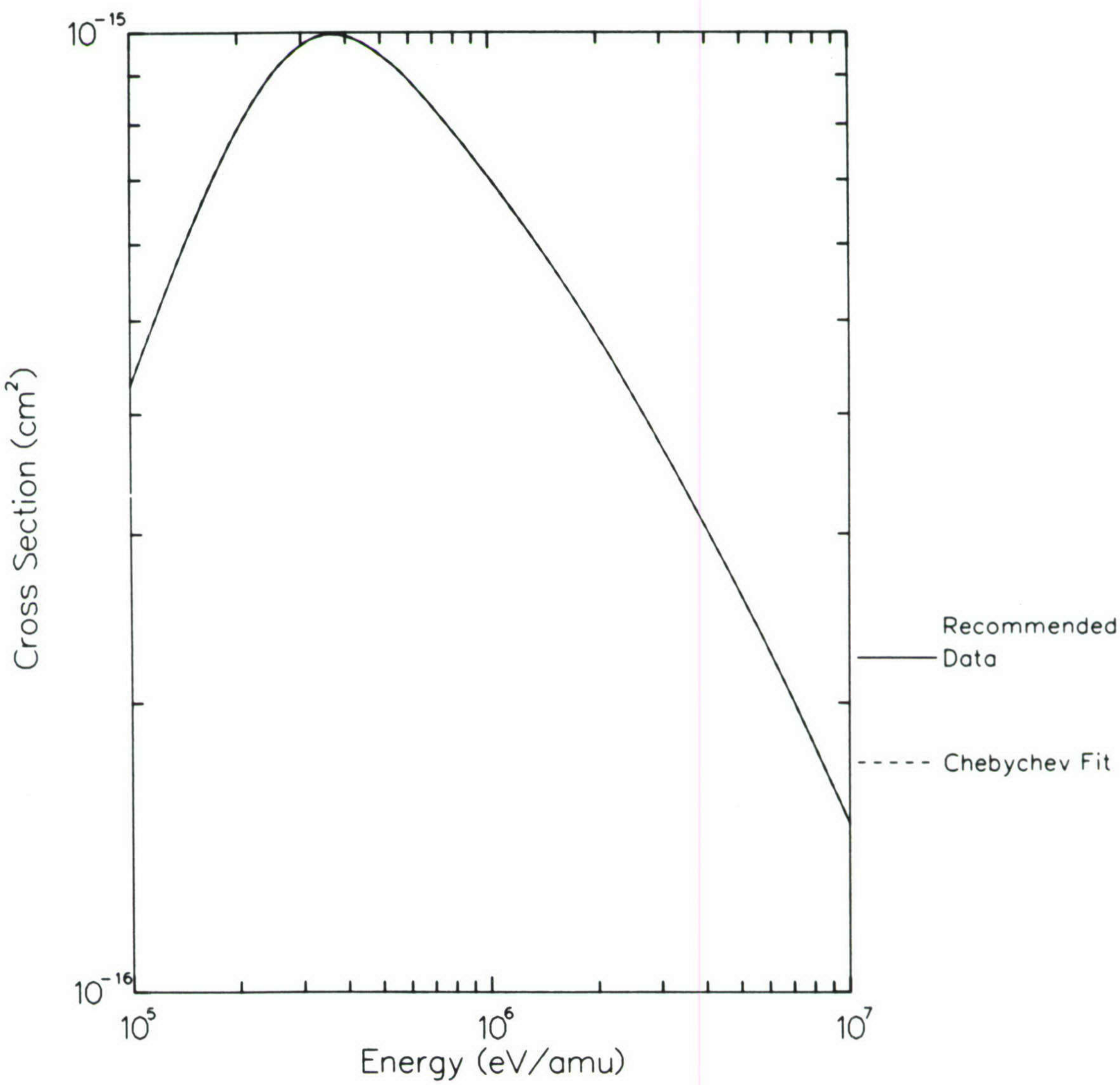
Chebychev Fitting Parameters for Cross Sections

C1	C2	C3	C4	C5	C6	C7	C8	C9
9.963E-16	-2.265E-16	-2.567E-16	1.662E-16	-9.304E-18	-5.152E-17	4.884E-17	-2.672E-17	7.509E-18

The fit represents the above cross sections with an rms deviation of 0.0%.
The maximum deviation is 0.1% at 4.0E+05 eV/amu.
See appendix for Chebychev fit details.

$O^{7+} + He \rightarrow O^{7+} + He^{+} + e^{-}$

Cross Section vs. Energy



Ionization Rate Coefficients for
$He + O^{7+} \rightarrow O^{7+} + He^{+} + e^{-}$

Beam - Maxwellian Rate Coefficients (cm^3/s)

O^{7+} Temp. (eV)	He Energy (eV/amu) 100000.	150000.	200000.	250000.	300000.	400000.	500000.
1.0E+00	9.40E-08*	3.43E-07	4.91E-07	6.22E-07	7.37E-07	8.69E-07	9.30E-07
2.0E+00	9.40E-08*	3.43E-07	4.91E-07	6.22E-07	7.37E-07	8.69E-07	9.30E-07
4.0E+00	9.41E-08**	3.43E-07	4.91E-07	6.22E-07	7.37E-07	8.69E-07	9.30E-07
7.0E+00	9.43E-08**	3.43E-07	4.91E-07	6.22E-07	7.37E-07	8.69E-07	9.30E-07
1.0E+01	9.43E-08**	3.43E-07	4.91E-07	6.22E-07	7.37E-07	8.69E-07	9.30E-07
2.0E+01	9.46E-08*	3.43E-07	4.91E-07	6.22E-07	7.37E-07	8.69E-07	9.30E-07
4.0E+01	9.49E-08*	3.43E-07	4.91E-07	6.22E-07	7.37E-07	8.69E-07	9.30E-07
7.0E+01	9.53E-08*	3.43E-07	4.91E-07	6.22E-07	7.37E-07	8.69E-07	9.30E-07
1.0E+02	9.56E-08*	3.43E-07	4.91E-07	6.22E-07	7.37E-07	8.69E-07	9.30E-07
2.0E+02	9.63E-08*	3.43E-07	4.91E-07	6.22E-07	7.37E-07	8.69E-07	9.30E-07
4.0E+02	9.74E-08*	3.43E-07	4.91E-07	6.23E-07	7.37E-07	8.69E-07	9.30E-07
7.0E+02	9.86E-08*	3.43E-07	4.91E-07	6.23E-07	7.37E-07	8.69E-07	9.30E-07
1.0E+03	9.96E-08*	3.43E-07	4.91E-07	6.23E-07	7.37E-07	8.69E-07	9.30E-07
2.0E+03	1.02E-07*	3.43E-07	4.91E-07	6.23E-07	7.36E-07	8.69E-07	9.30E-07
4.0E+03	1.06E-07*	3.44E-07	4.91E-07	6.23E-07	7.37E-07	8.69E-07	9.29E-07
7.0E+03	1.10E-07*	3.45E-07	4.92E-07	6.23E-07	7.37E-07	8.69E-07	9.29E-07
1.0E+04	1.13E-07*	3.45E-07	4.93E-07	6.24E-07	7.37E-07	8.69E-07	9.29E-07
2.0E+04	1.22E-07*	3.48E-07	4.94E-07	6.23E-07	7.36E-07	8.69E-07	9.28E-07

Accuracy: * - Possible Error Greater Than 10%
** - Possible Error Greater Than 100%

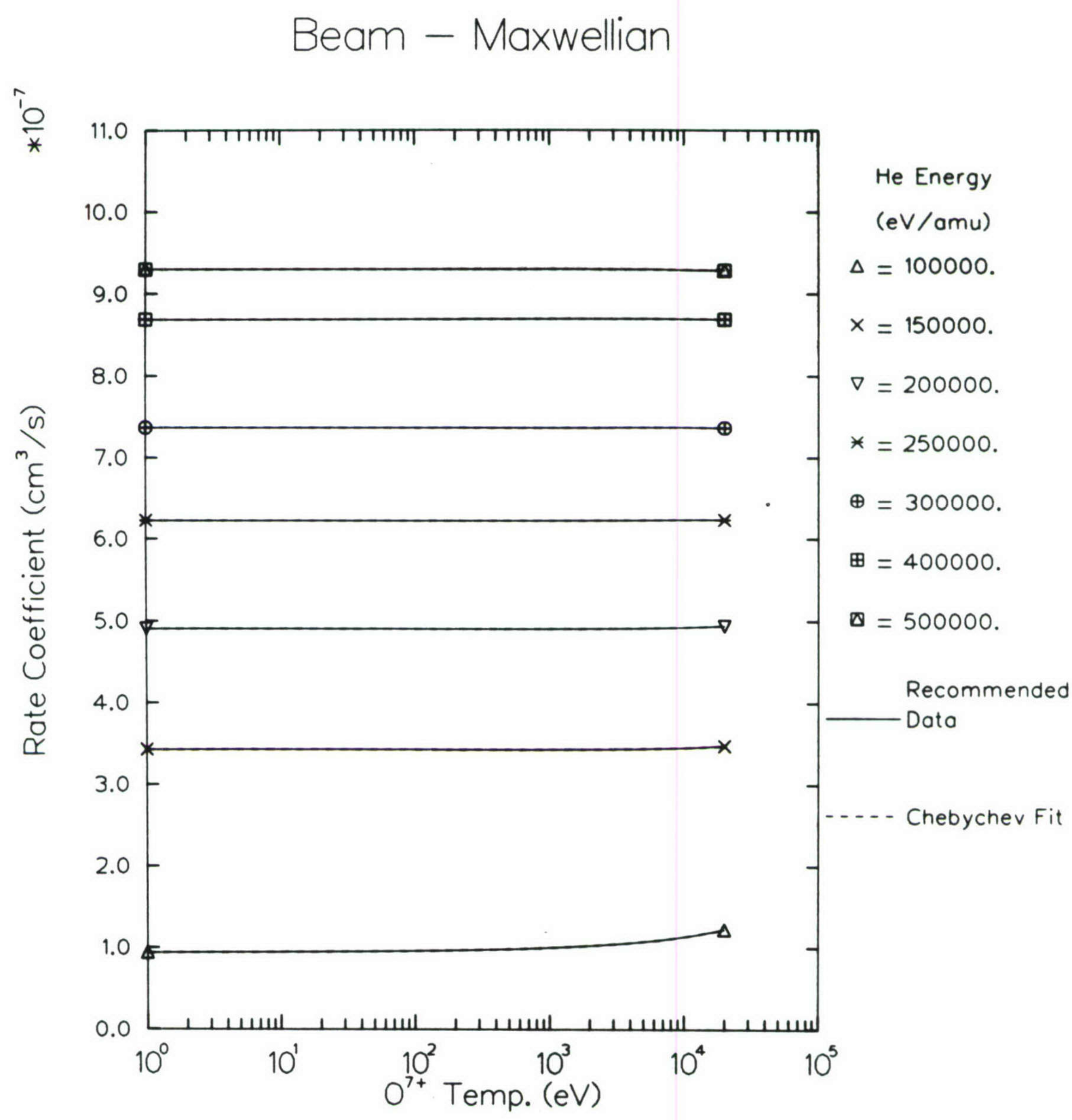
Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

Chebychev Fitting Parameters for Rate Coefficients

He Energy (eV/amu)	C1	C2	C3	C4	C5	C6	C7
100000.	2.025E-07	1.153E-08	6.037E-09	2.399E-09	7.849E-10	2.236E-10	5.751E-11
150000.	6.877E-07	1.614E-09	1.143E-09	6.539E-10	3.039E-10	1.114E-10	2.898E-11
200000.	9.827E-07	1.191E-09	8.562E-10	5.011E-10	2.489E-10	1.000E-10	3.706E-11
250000.	1.246E-06	5.028E-10	3.136E-10	9.678E-11	-2.657E-11	-6.969E-11	-7.132E-11
300000.	1.473E-06	4.907E-11	4.241E-12	-6.249E-11	-9.288E-11	-9.338E-11	-8.970E-11
400000.	1.738E-06	1.474E-10	-8.387E-11	-1.417E-10	-9.444E-11	-3.763E-11	-9.690E-13
500000.	1.859E-06	-4.727E-10	-3.416E-10	-1.786E-10	-5.899E-11	6.831E-12	4.669E-11

See appendix for Chebychev fit details.

$He + O^{7+} \rightarrow O^{7+} + He^{+} + e^{-}$



Ionization Cross Sections for
$O^{8+} + He \rightarrow O^{8+} + He^+ + e^-$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
1.0E+05	4.39E+08	2.61E-16
2.0E+05	6.21E+08	6.99E-16
4.0E+05	8.78E+08	9.25E-16
7.0E+05	1.16E+09	8.59E-16
1.0E+06	1.39E+09	7.75E-16
2.0E+06	1.96E+09	5.83E-16
4.0E+06	2.77E+09	3.85E-16
7.0E+06	3.65E+09	2.58E-16
1.0E+07	4.36E+09	1.95E-16

References: E.67, E.69, T.9, T.42, T.59, T.60, T.61

Accuracy: 40% for $E < 2x10^5$ eV/amu; 25% for $2x10^5 \leq E(eV/amu) < 4x10^5$; 15% for $E \geq 4x10^5$ eV/amu

Note: In the region above $4x10^5$ eV/amu the recommended cross section represents the experimental data [E.67], [E.69], the results of three-state close-coupling calculations [T.59] (up to $4x10^6$ eV/amu) and Bethe-Born approximation (see sect. 2.1.1). For energies below $4x10^5$ eV/amu, the cross section is based on three-state close-coupling theory [T.59] and classical-trajectory Monte Carlo calculations [T.9], [T.42].

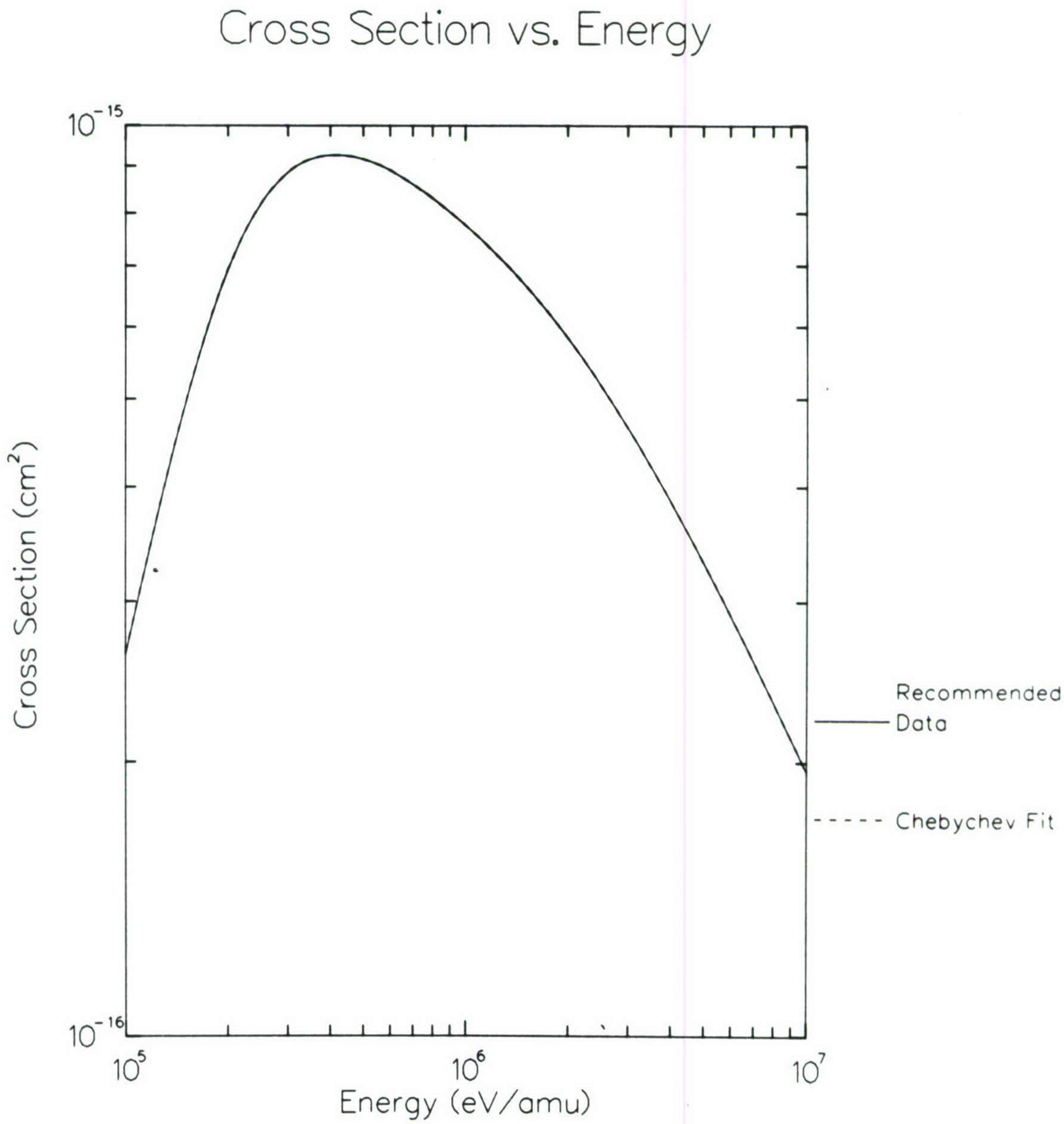
For Chebychev fits of the above cross sections it is necessary to use the following parameters.
E_{min} = 1.0E+05 eV/amu, E_{max} = 1.0E+07 eV/amu

Chebychev Fitting Parameters for Cross Sections

C1	C2	C3	C4	C5	C6	C7	C8	C9
1.001E-15	-1.301E-16	-2.988E-16	1.391E-16	-2.066E-18	-2.788E-17	2.529E-17	-1.408E-17	3.095E-18

The fit represents the above cross sections with an rms deviation of 0.0%.
The maximum deviation is 0.0% at 1.0E+06 eV/amu.
See appendix for Chebychev fit details.

$O^{8+} + He \rightarrow O^{8+} + He^{+} + e^{-}$



Ionization Rate Coefficients for
$He + O^{8+} \rightarrow O^{8+} + He^{+} + e^{-}$

Beam - Maxwellian Rate Coefficients (cm^3/s)

O^{8+} Temp. (eV)	He Energy (eV/amu) 100000.	150000.	200000.	250000.	300000.	400000.	500000.
1.0E+00	5.75E-08*	2.73E-07	5.10E-07	6.09E-07	6.82E-07	8.12E-07	9.11E-07
2.0E+00	5.75E-08*	2.72E-07	4.41E-07	5.76E-07	6.82E-07	8.12E-07	9.11E-07
4.0E+00	5.76E-08**	2.72E-07	4.34E-07	5.74E-07	6.82E-07	8.12E-07	9.11E-07
7.0E+00	5.77E-08**	2.72E-07	4.34E-07	5.74E-07	6.82E-07	8.13E-07	9.11E-07
1.0E+01	5.78E-08**	2.72E-07	4.34E-07	5.74E-07	6.82E-07	8.13E-07	9.11E-07
2.0E+01	5.80E-08*	2.72E-07	4.34E-07	5.74E-07	6.82E-07	8.13E-07	9.11E-07
4.0E+01	5.83E-08*	2.72E-07	4.34E-07	5.74E-07	6.82E-07	8.13E-07	9.11E-07
7.0E+01	5.86E-08*	2.72E-07	4.34E-07	5.74E-07	6.82E-07	8.13E-07	9.11E-07
1.0E+02	5.88E-08*	2.72E-07	4.34E-07	5.74E-07	6.82E-07	8.13E-07	9.11E-07
2.0E+02	5.95E-08*	2.72E-07	4.34E-07	5.74E-07	6.82E-07	8.13E-07	9.11E-07
4.0E+02	6.04E-08*	2.72E-07	4.34E-07	5.74E-07	6.82E-07	8.13E-07	9.11E-07
7.0E+02	6.14E-08*	2.72E-07	4.34E-07	5.74E-07	6.82E-07	8.13E-07	9.11E-07
1.0E+03	6.23E-08*	2.72E-07	4.34E-07	5.74E-07	6.82E-07	8.14E-07	9.11E-07
2.0E+03	6.44E-08*	2.73E-07	4.35E-07	5.74E-07	6.82E-07	8.14E-07	9.10E-07
4.0E+03	6.76E-08*	2.73E-07	4.35E-07	5.74E-07	6.82E-07	8.15E-07	9.10E-07
7.0E+03	7.13E-08*	2.74E-07	4.35E-07	5.74E-07	6.82E-07	8.15E-07	9.10E-07
1.0E+04	7.44E-08*	2.75E-07	4.36E-07	5.74E-07	6.82E-07	8.15E-07	9.10E-07
2.0E+04	8.27E-08*	2.78E-07	4.37E-07	5.74E-07	6.81E-07	8.16E-07	9.10E-07

Accuracy: * - Possible Error Greater Than 10%
** - Possible Error Greater Than 100%

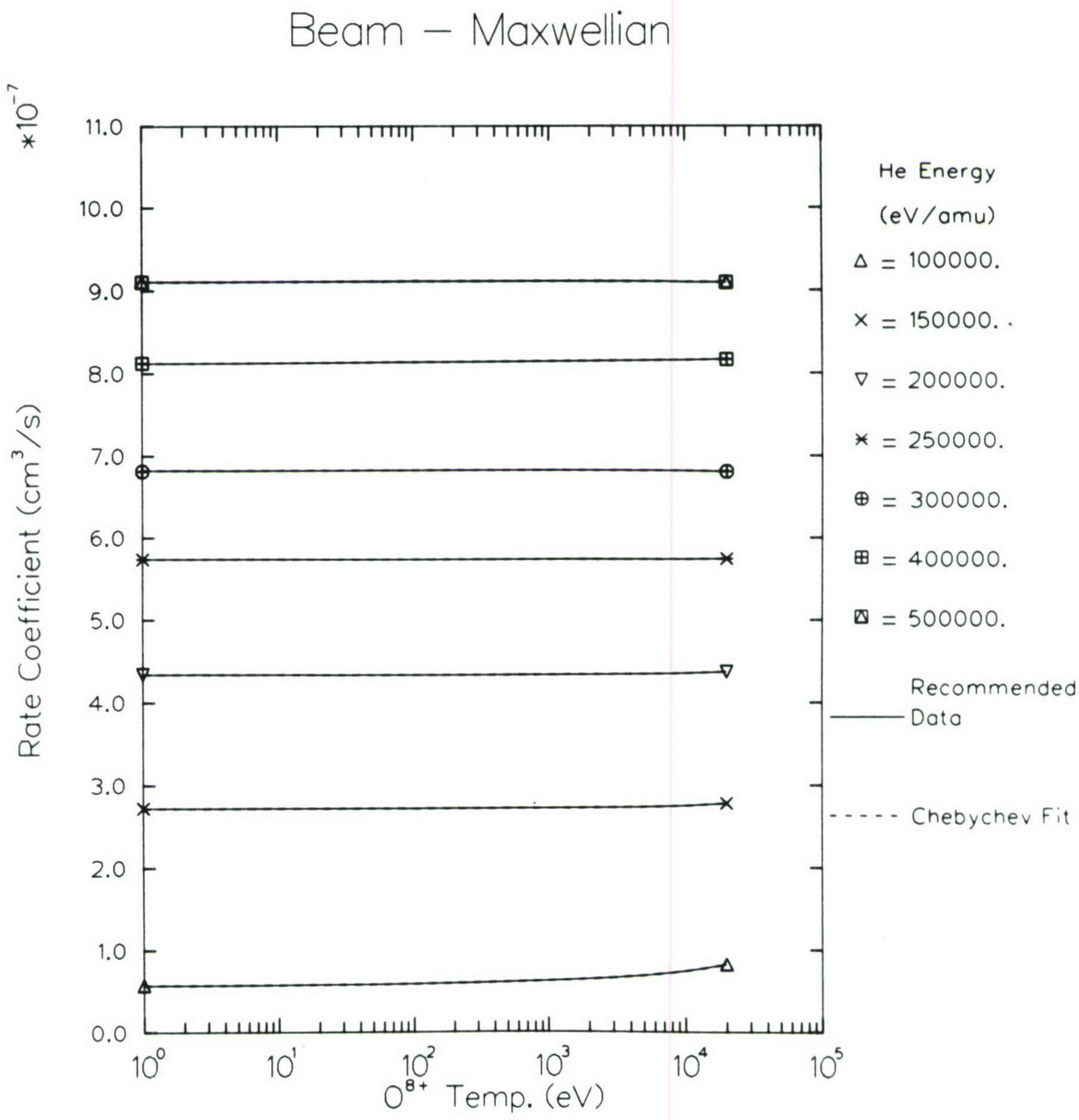
Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

Chebychev Fitting Parameters for Rate Coefficients

He Energy (eV/amu)	C1	C2	C3	C4	C5	C6	C7
100000.	1.277E-07	1.015E-08	5.407E-09	2.215E-09	7.583E-10	2.287E-10	6.216E-11
150000.	5.467E-07	1.936E-09	1.572E-09	6.955E-10	5.531E-10	2.202E-12	1.912E-10
200000.	8.861E-07	-1.529E-08	1.518E-08	-1.217E-08	9.810E-09	-6.910E-09	4.800E-09
250000.	1.155E-06	-7.462E-09	6.955E-09	-5.900E-09	4.641E-09	-3.380E-09	2.359E-09
300000.	1.364E-06	-4.452E-10	-3.050E-10	-2.207E-10	-1.102E-10	-7.103E-11	-2.813E-11
400000.	1.627E-06	1.686E-09	7.308E-10	1.893E-10	1.859E-11	-3.065E-12	9.378E-12
500000.	1.821E-06	-4.282E-10	-3.097E-10	-1.593E-10	-4.900E-11	1.138E-11	4.883E-11

See appendix for Chebychev fit details.

$He + O^{8+} \rightarrow O^{8+} + He^{+} + e^{-}$



Ionization Cross Sections for
$C^+ + H_2 \rightarrow C^+ + H_2^+ + e^-$

Energy	Velocity	Cross Section
1.5E+04	1.70E+08	5.16E-17
2.0E+04	1.96E+08	8.85E-17
4.0E+04	2.78E+08	2.09E-16
6.0E+04	3.40E+08	2.37E-16
7.0E+04	3.68E+08	2.32E-16
1.0E+05	4.39E+08	2.06E-16
2.0E+05	6.21E+08	1.43E-16
4.0E+05	8.78E+08	8.90E-17
7.0E+05	1.16E+09	5.82E-17
1.0E+06	1.39E+09	4.40E-17
2.0E+06	1.96E+09	2.43E-17
4.0E+06	2.77E+09	1.30E-17
7.0E+06	3.65E+09	7.84E-18
1.0E+07	4.36E+09	5.76E-18

References: T.60

Accuracy: 40% for $E < 4\times10^4$ eV/amu; 30% for $E \geq 4\times10^4$ eV/amu

Notes: (1) The recommended cross section has been constructed on the basis of the semi-empirical scaling formula [T.60], using also the empirical scalings for E_m (the energy of the cross section maximum) and $\sigma(E_m)$ for $C^{q+} + H_2$ (q = 2-4), derived from experimental data in Ref. [E.69] (see sect. 2.1.1).
(2) The recommended cross section represents the non-dissociative ionization channel only which produces H_2^+. The calculated reaction rate coefficients also refer to this channel.

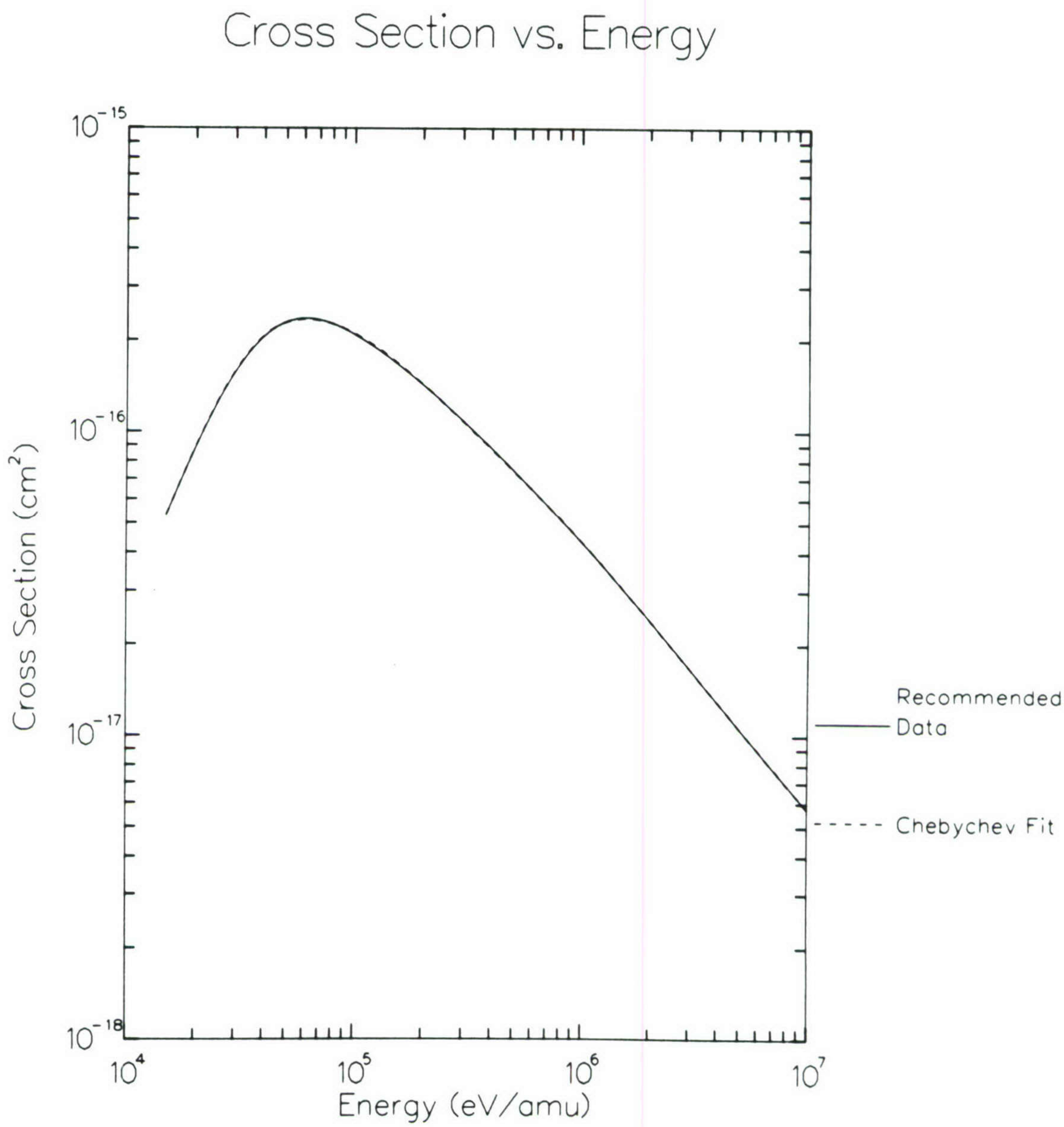
For Chebychev fits of the above cross sections it is necessary to use the following parameters.
E_{min} = 1.5E+04 eV/amu, E_{max} = 1.0E+07 eV/amu

Chebychev Fitting Parameters for Cross Sections

C1	C2	C3	C4	C5	C6	C7	C8	C9
1.657E-16	-7.306E-17	-4.128E-17	5.980E-17	-2.568E-17	-2.397E-18	1.052E-17	-7.260E-18	2.259E-18

The fit represents the above cross sections with an rms deviation of 0.8%.
The maximum deviation is 1.6% at 1.0E+05 eV/amu.
See appendix for Chebychev fit details.

$C^+ + H_2 \rightarrow C^+ + H_2^+ + e^-$



Ionization Rate Coefficients for
$H_2 + C^+ \rightarrow C^+ + H_2^+ + e^-$

Beam - Maxwellian Rate Coefficients (cm^3/s)

C^+ Temp. (eV)	H_2 Energy (eV/amu) 15000.	30000.	50000.	70000.	100000.	200000.	500000.
1.0E+00	4.43E-09**	3.80E-08	7.20E-08	8.53E-08	9.05E-08	8.88E-08	7.41E-08
2.0E+00	4.44E-09**	3.80E-08	7.20E-08	8.53E-08	9.05E-08	8.88E-08	7.41E-08
4.0E+00	4.46E-09*	3.80E-08	7.20E-08	8.53E-08	9.05E-08	8.88E-08	7.41E-08
7.0E+00	4.49E-09*	3.80E-08	7.20E-08	8.53E-08	9.05E-08	8.88E-08	7.41E-08
1.0E+01	4.50E-09*	3.80E-08	7.20E-08	8.53E-08	9.05E-08	8.88E-08	7.41E-08
2.0E+01	4.55E-09*	3.80E-08	7.20E-08	8.53E-08	9.05E-08	8.88E-08	7.41E-08
4.0E+01	4.62E-09*	3.80E-08	7.20E-08	8.53E-08	9.05E-08	8.88E-08	7.41E-08
7.0E+01	4.70E-09*	3.80E-08	7.20E-08	8.53E-08	9.05E-08	8.88E-08	7.41E-08
1.0E+02	4.76E-09*	3.80E-08	7.20E-08	8.53E-08	9.05E-08	8.88E-08	7.41E-08
2.0E+02	4.93E-09*	3.80E-08	7.20E-08	8.53E-08	9.05E-08	8.88E-08	7.41E-08
4.0E+02	5.17E-09*	3.81E-08	7.20E-08	8.53E-08	9.05E-08	8.88E-08	7.41E-08
7.0E+02	5.45E-09*	3.81E-08	7.19E-08	8.53E-08	9.05E-08	8.89E-08	7.41E-08
1.0E+03	5.69E-09*	3.82E-08	7.19E-08	8.53E-08	9.05E-08	8.89E-08	7.41E-08
2.0E+03	6.33E-09*	3.84E-08	7.18E-08	8.50E-08	9.05E-08	8.89E-08	7.41E-08
4.0E+03	7.34E-09*	3.89E-08	7.17E-08	8.51E-08	9.05E-08	8.88E-08	7.41E-08
7.0E+03	8.61E-09*	3.96E-08	7.14E-08	8.48E-08	9.05E-08	8.89E-08	7.41E-08
1.0E+04	9.74E-09*	4.01E-08	7.12E-08	8.47E-08	9.04E-08	8.89E-08	7.39E-08
2.0E+04	1.30E-08*	4.18E-08	7.06E-08	8.38E-08	9.01E-08	8.87E-08	7.41E-08

Accuracy: * - Possible Error Greater Than 10%
** - Possible Error Greater Than 100%

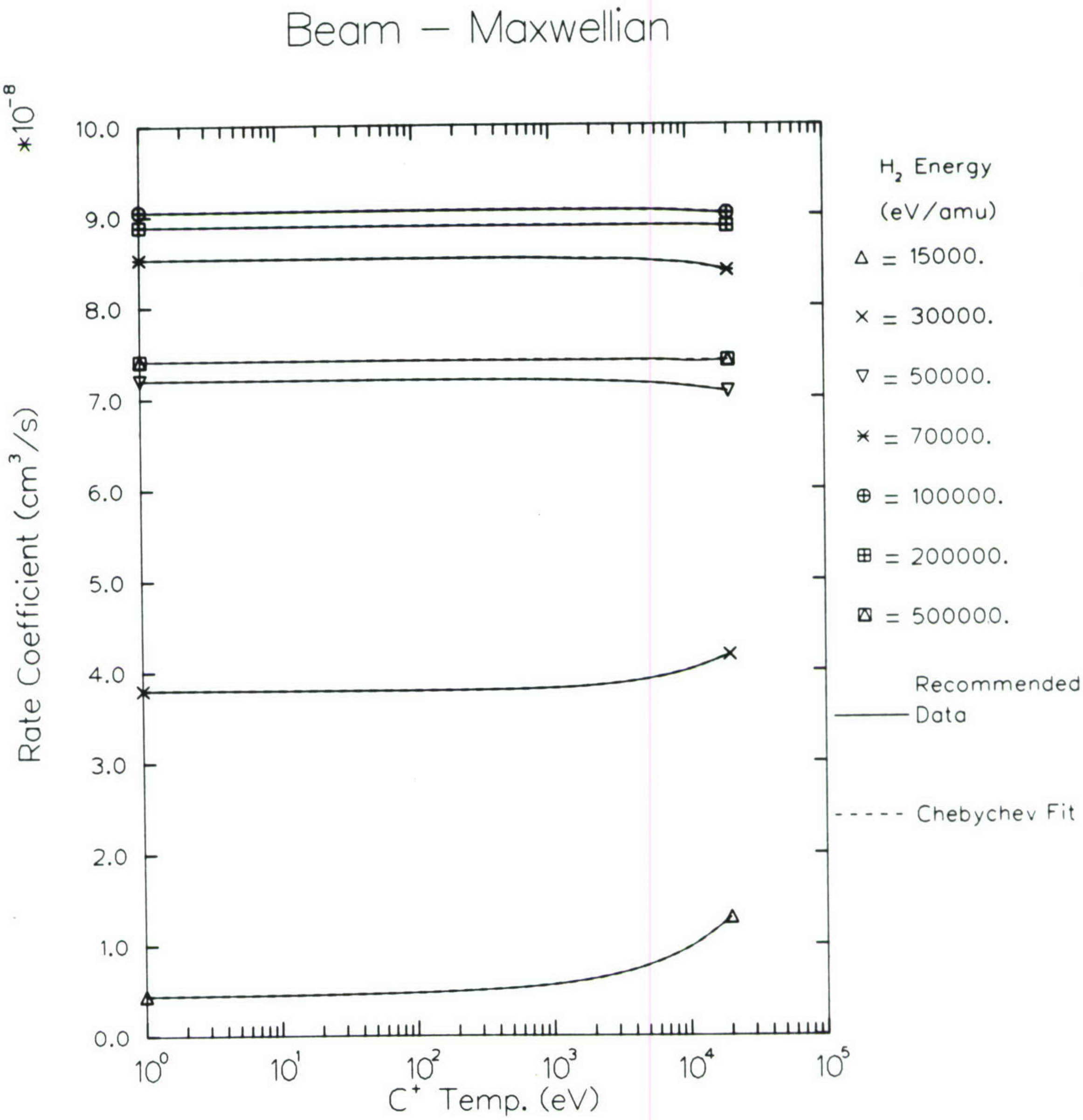
Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

Chebychev Fitting Parameters for Rate Coefficients

H_2 Energy (eV/amu)	C1	C2	C3	C4	C5	C6	C7
15000.	1.284E-08	3.271E-09	1.904E-09	8.944E-10	3.617E-10	1.275E-10	3.695E-11
30000.	7.744E-08	1.336E-09	9.198E-10	4.968E-10	2.079E-10	6.341E-11	1.078E-11
50000.	1.435E-07	-4.905E-10	-3.350E-10	-1.784E-10	-7.385E-11	-2.329E-11	-3.512E-12
70000.	1.701E-07	-4.419E-10	-3.376E-10	-2.074E-10	-1.035E-10	-4.990E-11	-3.602E-11
100000.	1.809E-07	-8.134E-11	-9.684E-11	-7.460E-11	-4.031E-11	-1.592E-11	-3.505E-12
200000.	1.777E-07	-6.747E-12	-2.481E-11	-2.693E-11	-1.853E-11	-1.038E-11	-7.153E-12
500000.	1.482E-07	-3.942E-11	-2.916E-11	-9.135E-12	5.565E-12	1.299E-11	1.941E-11

See appendix for Chebychev fit details.

$H_2 + C^+ \rightarrow C^+ + H_2^+ + e^-$



Ionization Cross Sections for
$C^{2+} + H_2 \rightarrow C^{2+} + H_2^+ + e^-$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
1.3E+04	1.58E+08	1.75E-16
2.0E+04	1.96E+08	2.39E-16
4.0E+04	2.78E+08	4.11E-16
7.0E+04	3.68E+08	5.51E-16
1.0E+05	4.39E+08	5.71E-16
2.0E+05	6.21E+08	4.75E-16
4.0E+05	8.78E+08	3.03E-16
7.0E+05	1.16E+09	2.03E-16
1.0E+06	1.39E+09	1.55E-16
2.0E+06	1.96E+09	8.84E-17
4.0E+06	2.77E+09	4.85E-17
7.0E+06	3.65E+09	3.00E-17
1.0E+07	4.36E+09	2.20E-17

References: E.70, T.60

Accuracy: 15% for $E \leq 2\times10^5$ eV/amu; 20% for $E > 2\times10^5$ eV/amu

Notes: (1) The recommended cross section is determined by the experimental data in the energy range $1.5\times10^4 \leq E(\text{eV/amu}) \leq 2\times10^5$, and represents the non-dissociative channel (producing H_2^+).
(2) The cross section for $E > 2\times10^5$ eV/amu is based on the semi-empirical scaling [T.60] (see sect. 2.1.1) which in the energy region around the cross section maximum gives results that coincide with experimental data.
(3) The dotted curve in the figure is the measured total cross section for the dissociative ionization channels (15% accuracy). (see sect. 2.1.3)
(4) The calculated reaction rate coefficients are for the non-dissociative ionization channel only.

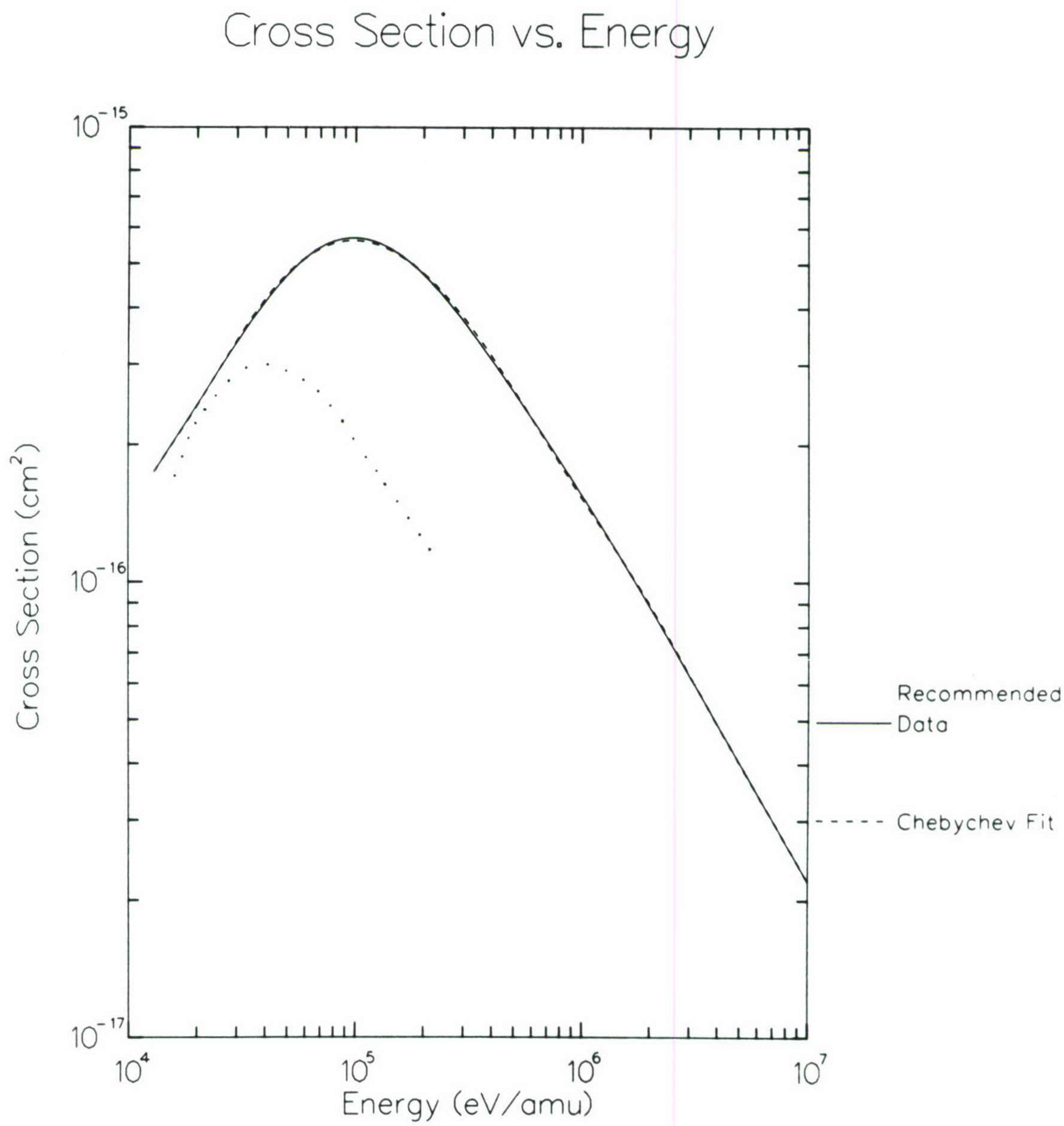
For Chebychev fits of the above cross sections it is necessary to use the following parameters.
E_{min} = 1.3E+04 eV/amu, E_{max} = 1.0E+07 eV/amu

Chebychev Fitting Parameters for Cross Sections

C1	C2	C3	C4	C5	C6	C7	C8	C9
4.465E-16	-1.597E-16	-1.395E-16	1.223E-16	1.801E-18	-4.504E-17	2.005E-17	5.824E-18	-6.981E-18

The fit represents the above cross sections with an rms deviation of 1.7%.
The maximum deviation is 3.3% at 4.0E+05 eV/amu.
See appendix for Chebychev fit details.

$C^{2+} + H_2 -> C^{2+} + H_2^{+} + e^{-}$



Cross Section vs. Energy
Cross Section (cm^2)
10^-15
10^-16
10^-17
10^4
10^5
10^6
10^7
Energy (eV/amu)
Recommended Data
Chebychev Fit

Ionization Rate Coefficients for
$H_2 + C^{2+} \rightarrow C^{2+} + H_2^+ + e^-$

Beam - Maxwellian Rate Coefficients (cm^3/s)

C^{2+} Temp. (eV)	H_2 Energy (eV/amu) 15000.	30000.	50000.	70000.	100000.	200000.	500000.
1.0E+00	3.29E-08	7.85E-08	1.46E-07	2.03E-07	2.51E-07	2.95E-07	2.55E-07
2.0E+00	3.30E-08	7.85E-08	1.46E-07	2.02E-07	2.51E-07	2.95E-07	2.55E-07
4.0E+00	3.30E-08	7.85E-08	1.46E-07	2.02E-07	2.51E-07	2.95E-07	2.55E-07
7.0E+00	3.30E-08	7.85E-08	1.46E-07	2.02E-07	2.51E-07	2.95E-07	2.55E-07
1.0E+01	3.30E-08	7.85E-08	1.46E-07	2.02E-07	2.51E-07	2.95E-07	2.55E-07
2.0E+01	3.30E-08	7.85E-08	1.46E-07	2.02E-07	2.51E-07	2.95E-07	2.55E-07
4.0E+01	3.30E-08	7.85E-08	1.46E-07	2.02E-07	2.51E-07	2.95E-07	2.55E-07
7.0E+01	3.30E-08	7.85E-08	1.46E-07	2.02E-07	2.51E-07	2.95E-07	2.55E-07
1.0E+02	3.30E-08	7.85E-08	1.46E-07	2.02E-07	2.51E-07	2.95E-07	2.55E-07
2.0E+02	3.30E-08	7.86E-08	1.46E-07	2.02E-07	2.51E-07	2.95E-07	2.55E-07
4.0E+02	3.26E-08	7.87E-08	1.46E-07	2.02E-07	2.51E-07	2.95E-07	2.55E-07
7.0E+02	3.18E-08	7.89E-08	1.46E-07	2.02E-07	2.51E-07	2.95E-07	2.55E-07
1.0E+03	3.11E-08	7.90E-08	1.46E-07	2.02E-07	2.51E-07	2.95E-07	2.55E-07
2.0E+03	2.98E-08*	7.95E-08	1.46E-07	2.02E-07	2.51E-07	2.95E-07	2.55E-07
4.0E+03	2.93E-08*	8.06E-08	1.47E-07	2.02E-07	2.51E-07	2.95E-07	2.55E-07
7.0E+03	2.99E-08*	8.20E-08	1.48E-07	2.01E-07	2.51E-07	2.95E-07	2.54E-07
1.0E+04	3.10E-08*	8.34E-08	1.48E-07	2.02E-07	2.50E-07	2.95E-07	2.54E-07
2.0E+04	3.54E-08*	8.75E-08	1.51E-07	2.01E-07	2.50E-07	2.94E-07	2.54E-07

Accuracy: * - Possible Error Greater Than 10%
** - Possible Error Greater Than 100%

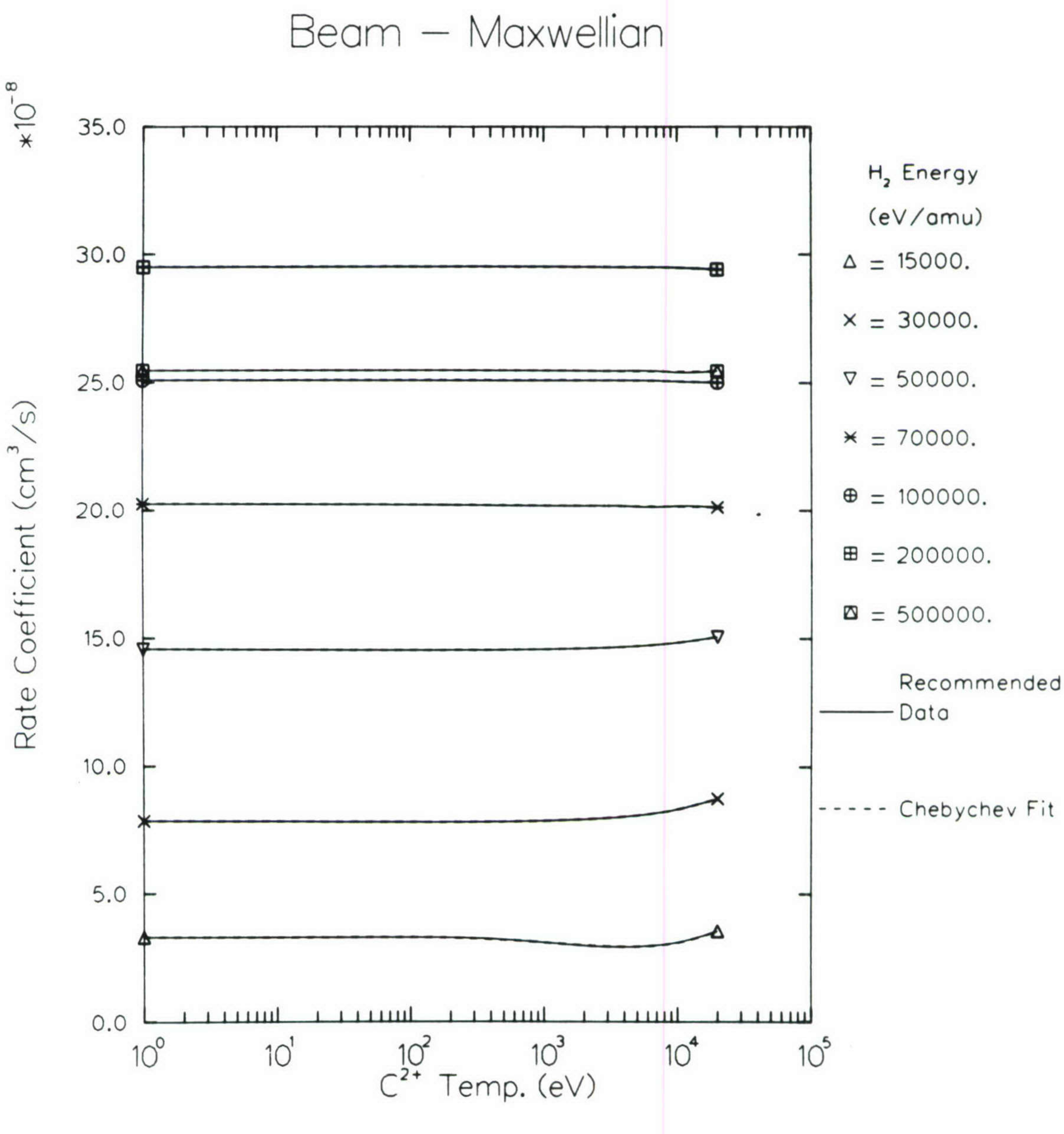
Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

Chebychev Fitting Parameters for Rate Coefficients

H_2 Energy (eV/amu)	C1	C2	C3	C4	C5	C6	C7
15000.	6.483E-08	-5.933E-10	5.360E-10	1.293E-09	1.230E-09	6.192E-10	2.231E-11
30000.	1.605E-07	3.115E-09	2.175E-09	1.217E-09	5.428E-10	1.896E-10	4.699E-11
50000.	2.934E-07	1.704E-09	1.179E-09	6.578E-10	2.828E-10	9.687E-11	1.696E-11
70000.	4.042E-07	-6.059E-10	-2.209E-10	-5.184E-11	4.386E-12	-4.206E-12	-6.263E-12
100000.	5.014E-07	-2.315E-10	-2.248E-10	-1.550E-10	-7.706E-11	-2.719E-11	-2.412E-12
200000.	5.899E-07	-2.342E-10	-2.347E-10	-1.797E-10	-1.059E-10	-5.276E-11	-3.045E-11
500000.	5.091E-07	-1.314E-10	-9.719E-11	-2.918E-11	2.067E-11	4.571E-11	6.759E-11

See appendix for Chebychev fit details.

$H_2 + C^{2+} \rightarrow C^{2+} + H_2^+ + e^-$



Ionization Cross Sections for
$C^{3+} + H_2 \rightarrow C^{3+} + H_2^+ + e^-$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
2.0E+04	1.96E+08	9.98E-17
4.0E+04	2.78E+08	3.66E-16
7.0E+04	3.68E+08	7.76E-16
1.0E+05	4.39E+08	8.94E-16
1.3E+05	5.01E+08	9.15E-16
2.0E+05	6.21E+08	8.34E-16
4.0E+05	8.78E+08	5.69E-16
7.0E+05	1.16E+09	4.00E-16
1.0E+06	1.39E+09	3.11E-16
2.0E+06	1.96E+09	1.84E-16
4.0E+06	2.77E+09	1.05E-16
7.0E+06	3.65E+09	6.51E-17
1.0E+07	4.36E+09	4.83E-17

References: E.70, T.60

Accuracy: 15% for $E < 2\times10^5$ eV/amu; 20% for $E > 2\times10^5$ eV/amu

Notes: (1) The recommended cross section is determined by the experimental data over the energy range $2\times10^4 \le E(\text{eV/amu}) \le 2\times10^5$, and represents non-dissociative ionization only (producing H_2^+).
(2) The cross section in the region $E > 2\times10^5$ eV/amu has been constructed on the basis of semi-empirical scaling [T.60] (see sect. 2.1.1) by normalizing calculated data to experiment in the region $E \le 2\times10^5$ eV/amu, and retaining the proper high-energy Bethe-Born behavior of the cross section.
(3) The dotted line in the figure is the measured total cross section for the dissociative ionization channels [E.70] (accuracy 15%), (See sect. 2.1.3).
(4) The calculated reaction rate coefficients are for the non-dissociative ionization channel.

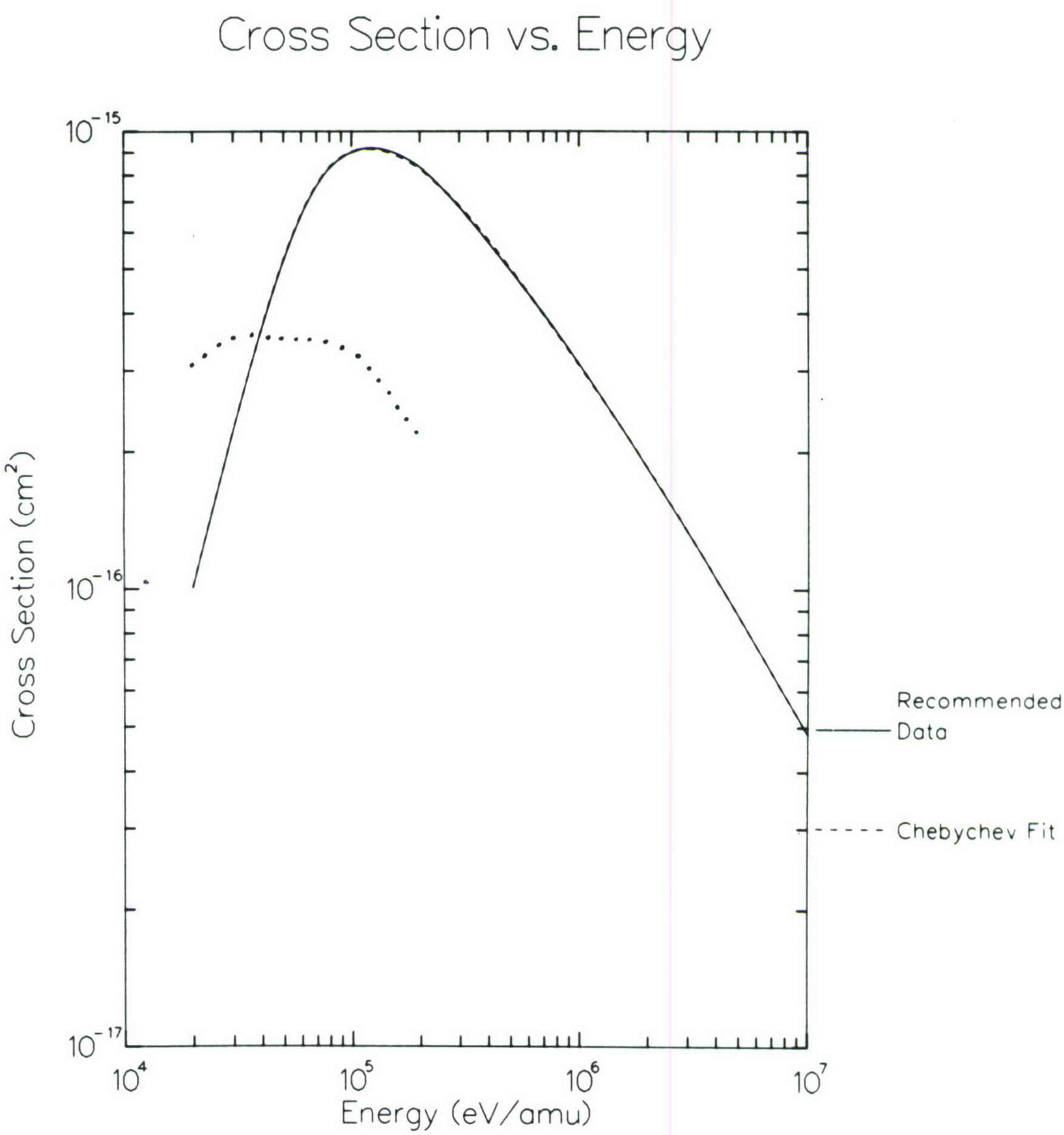
For Chebychev fits of the above cross sections it is necessary to use the following parameters.
E_{min} = 2.0E+04 eV/amu, E_{max} = 1.0E+07 eV/amu

Chebychev Fitting Parameters for Cross Sections

C1	C2	C3	C4	C5	C6	C7	C8	C9
6.292E-16	-1.477E-16	-2.981E-16	2.282E-16	-1.030E-17	-8.313E-17	6.510E-17	-2.316E-17	2.732E-18

The fit represents the above cross sections with an rms deviation of 0.8%.
The maximum deviation is 1.9% at 4.0E+05 eV/amu.
See appendix for Chebychev fit details.

$C^{3+} + H_2 \rightarrow C^{3+} + H_2^+ + e^-$



Ionization Rate Coefficients for
$H_2 + C^{3+} \rightarrow C^{3+} + H_2^{+} + e^-$

Beam - Maxwellian Rate Coefficients (cm^3/s)

C^{3+} Temp. (eV)	H_2 Energy (eV/amu) 20000.	30000.	50000.	70000.	100000.	200000.	500000.
1.0E+00	9.87E-09**	5.39E-08	1.58E-07	2.85E-07	3.93E-07	5.18E-07	4.88E-07
2.0E+00	9.90E-09**	5.40E-08	1.58E-07	2.85E-07	3.93E-07	5.18E-07	4.88E-07
4.0E+00	9.95E-09*	5.40E-08	1.58E-07	2.85E-07	3.93E-07	5.18E-07	4.88E-07
7.0E+00	9.99E-09*	5.40E-08	1.58E-07	2.85E-07	3.93E-07	5.18E-07	4.88E-07
1.0E+01	1.00E-08*	5.40E-08	1.58E-07	2.85E-07	3.93E-07	5.18E-07	4.88E-07
2.0E+01	1.01E-08*	5.40E-08	1.58E-07	2.85E-07	3.93E-07	5.18E-07	4.88E-07
4.0E+01	1.03E-08*	5.40E-08	1.58E-07	2.85E-07	3.93E-07	5.18E-07	4.88E-07
7.0E+01	1.04E-08*	5.40E-08	1.58E-07	2.85E-07	3.93E-07	5.18E-07	4.88E-07
1.0E+02	1.06E-08*	5.40E-08	1.58E-07	2.85E-07	3.93E-07	5.18E-07	4.88E-07
2.0E+02	1.09E-08*	5.41E-08	1.59E-07	2.84E-07	3.93E-07	5.18E-07	4.88E-07
4.0E+02	1.14E-08*	5.43E-08	1.59E-07	2.84E-07	3.93E-07	5.18E-07	4.88E-07
7.0E+02	1.19E-08*	5.46E-08	1.59E-07	2.84E-07	3.94E-07	5.18E-07	4.88E-07
1.0E+03	1.24E-08*	5.48E-08	1.59E-07	2.84E-07	3.94E-07	5.18E-07	4.88E-07
2.0E+03	1.37E-08*	5.57E-08	1.60E-07	2.83E-07	3.94E-07	5.18E-07	4.88E-07
4.0E+03	1.58E-08*	5.73E-08	1.62E-07	2.83E-07	3.94E-07	5.18E-07	4.88E-07
7.0E+03	1.84E-08*	5.95E-08	1.65E-07	2.83E-07	3.94E-07	5.18E-07	4.87E-07
1.0E+04	2.08E-08*	6.18E-08	1.68E-07	2.83E-07	3.94E-07	5.18E-07	4.86E-07
2.0E+04	2.82E-08*	6.96E-08	1.76E-07	2.84E-07	3.93E-07	5.16E-07	4.87E-07

Accuracy: * - Possible Error Greater Than 10%
** - Possible Error Greater Than 100%

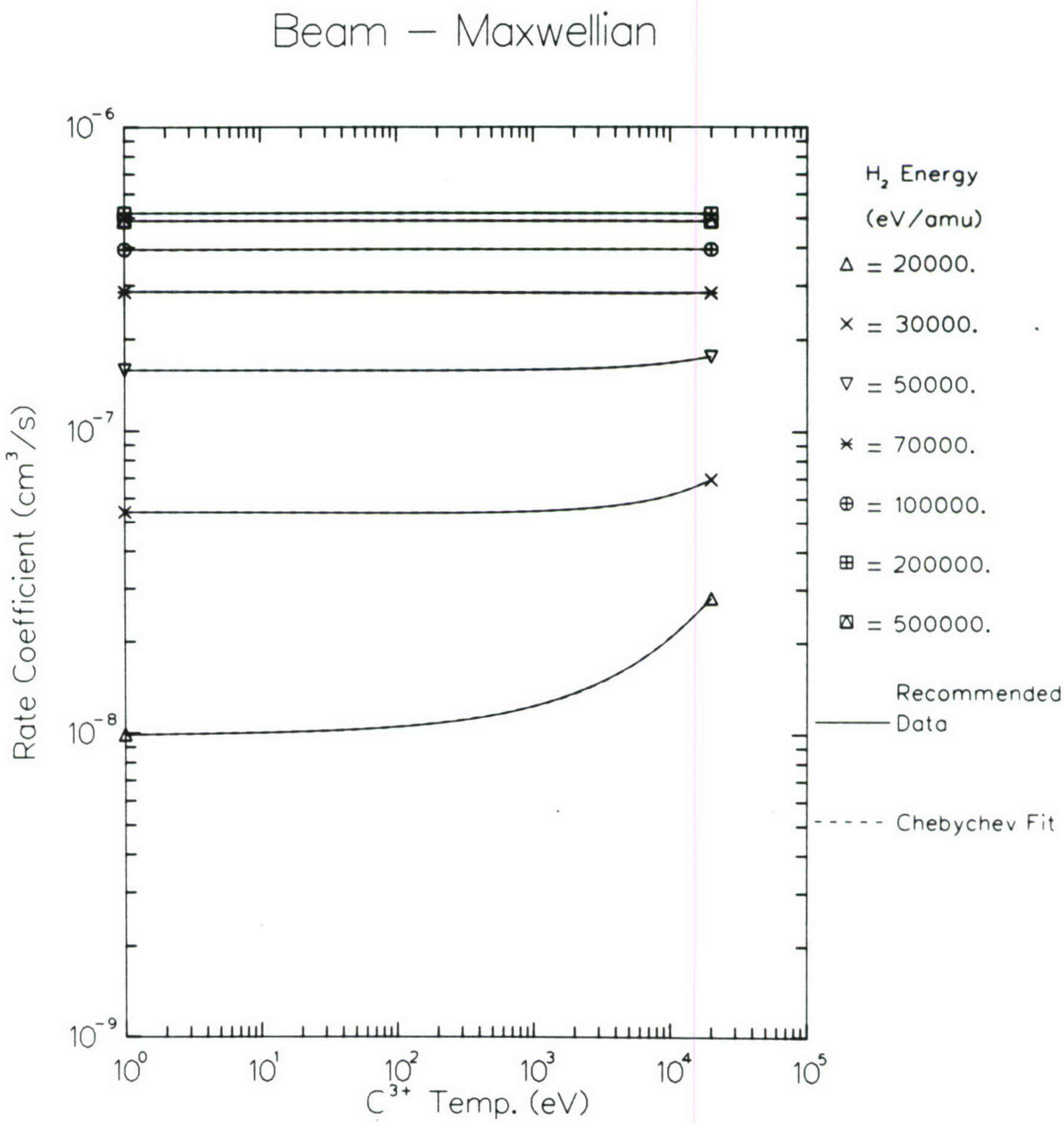
Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

Chebychev Fitting Parameters for Rate Coefficients

H_2 Energy (eV/amu)	C1	C2	C3	C4	C5	C6	C7
20000.	2.802E-08	6.823E-09	4.044E-09	1.970E-09	8.440E-10	3.227E-10	1.050E-10
30000.	1.137E-07	5.231E-09	3.670E-09	2.156E-09	1.026E-09	4.367E-10	1.587E-10
50000.	3.234E-07	5.955E-09	4.180E-09	2.374E-09	1.075E-09	3.886E-10	9.477E-11
70000.	5.685E-07	-1.092E-09	-9.214E-11	2.786E-10	2.272E-10	1.042E-10	3.144E-11
100000.	7.865E-07	6.611E-10	2.500E-11	-2.038E-10	-1.589E-10	-7.286E-11	-3.124E-11
200000.	1.036E-06	-3.598E-10	-3.985E-10	-3.196E-10	-1.923E-10	-9.635E-11	-5.553E-11
500000.	9.751E-07	-2.556E-10	-1.891E-10	-5.679E-11	4.017E-11	8.888E-11	1.314E-10

See appendix for Chebychev fit details.

$H_2 + C^{3+} \rightarrow C^{3+} + H_2^+ + e^-$



Ionization Cross Sections for
$C^{4+} + H_2 \rightarrow C^{4+} + H_2^+ + e^-$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
3.0E+04	2.41E+08	2.02E-16
4.0E+04	2.78E+08	4.03E-16
7.0E+04	3.68E+08	9.43E-16
1.0E+05	4.39E+08	1.18E-15
1.5E+05	5.38E+08	1.31E-15
2.0E+05	6.21E+08	1.27E-15
4.0E+05	8.78E+08	9.84E-16
7.0E+05	1.16E+09	6.96E-16
1.0E+06	1.39E+09	5.48E-16
2.0E+06	1.96E+09	3.16E-16
4.0E+06	2.77E+09	1.84E-16
7.0E+06	3.65E+09	1.18E-16
1.0E+07	4.36E+09	8.91E-17

References: E.70, E.71, T.60

Accuracy: 15% over the entire energy region shown

Notes: (1) The recommended cross section in the region $E \leq 2x10^5$ eV/amu represents the experimental data of [E.70]. For $E > 2x10^5$ eV/amu the cross section has been constructed by using the semi-empirical scaling formula [T.60] (see sect. 2.1.1), with normalization to the experimental data around the cross section maximum and at $E = 1.1x10^6$ eV/amu ([E.71]), and retaining the correct high-energy Bethe-Born behavior. The solid curve represents the non-dissociation ionization channel only (producing H_2^+).

(2) The dotted curve in the figure represents the total cross section for the dissociative ionization channels [E.70] (accuracy 15%), (See sect. 2.1.3).

(3) The calculated reaction rate coefficients are for the non-dissociative ionization channel only.

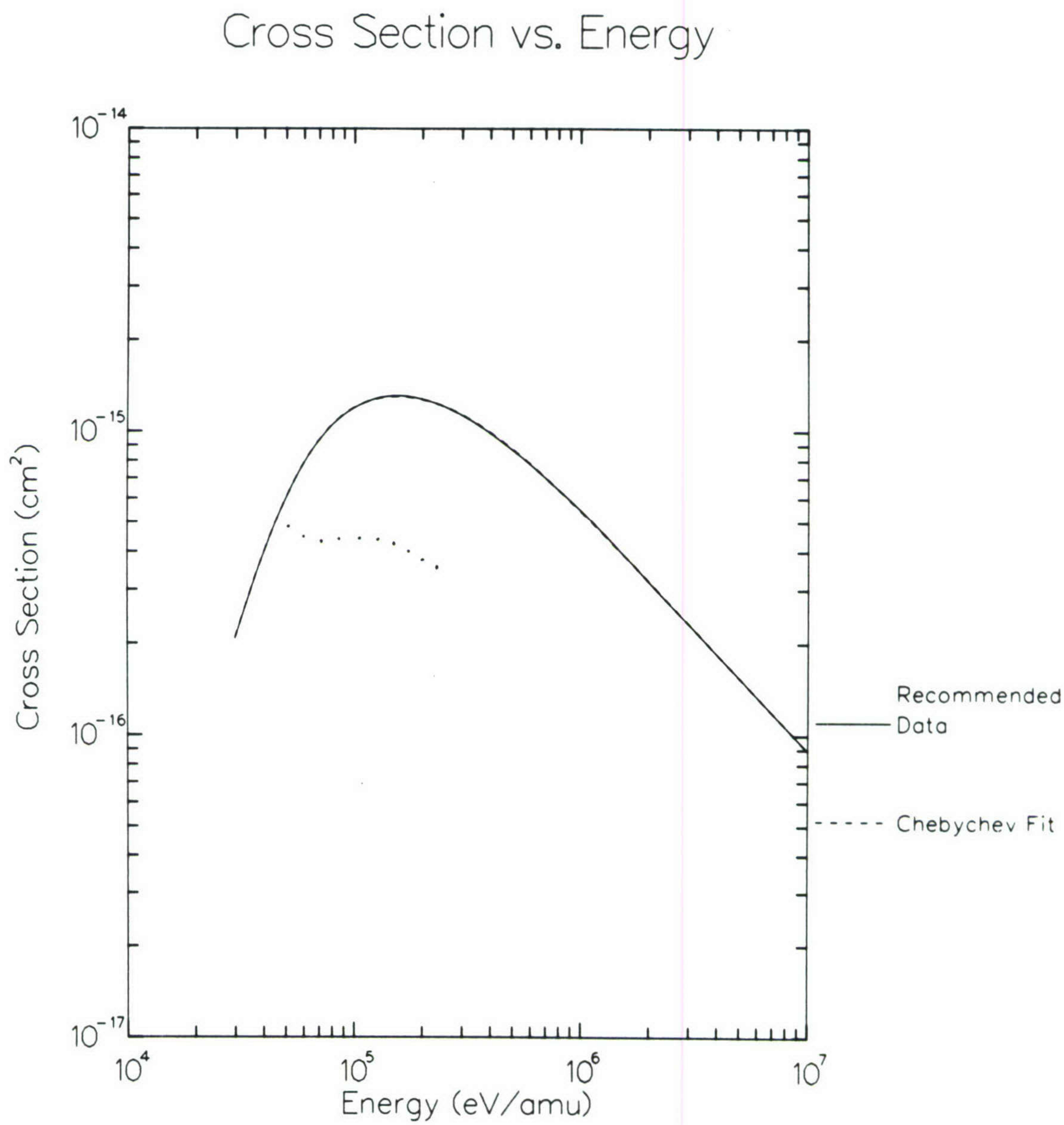
For Chebychev fits of the above cross sections it is necessary to use the following parameters.
E_{min} = 3.0E+04 eV/amu, E_{max} = 1.0E+07 eV/amu

Chebychev Fitting Parameters for Cross Sections

C1	C2	C3	C4	C5	C6	C7	C8	C9
1.049E-15	-2.937E-16	-3.825E-16	3.125E-16	-3.765E-17	-6.742E-17	4.266E-17	-7.805E-18	-1.507E-18

The fit represents the above cross sections with an rms deviation of 0.6%.
The maximum deviation is 0.7% at 7.0E+05 eV/amu.
See appendix for Chebychev fit details.

$C^{4+} + H_2 \to C^{4+} + H_2^+ + e^-$



Ionization Rate Coefficients for
$H_2 + C^{4+} \rightarrow C^{4+} + H_2^+ + e^-$

Beam - Maxwellian Rate Coefficients (cm^3/s)

C^{4+} Temp. (eV)	H_2 Energy (eV/amu) 30000.	50000.	70000.	100000.	200000.	400000.	500000.
1.0E+00	2.45E-08**	1.90E-07	3.47E-07	5.18E-07	7.89E-07	8.64E-07	8.54E-07
2.0E+00	2.45E-08**	1.90E-07	3.47E-07	5.18E-07	7.89E-07	8.64E-07	8.54E-07
4.0E+00	2.46E-08**	1.90E-07	3.47E-07	5.18E-07	7.89E-07	8.64E-07	8.54E-07
7.0E+00	2.48E-08*	1.90E-07	3.47E-07	5.18E-07	7.89E-07	8.64E-07	8.54E-07
1.0E+01	2.48E-08*	1.90E-07	3.47E-07	5.18E-07	7.89E-07	8.64E-07	8.54E-07
2.0E+01	2.51E-08*	1.90E-07	3.47E-07	5.19E-07	7.89E-07	8.64E-07	8.54E-07
4.0E+01	2.54E-08*	1.90E-07	3.47E-07	5.19E-07	7.89E-07	8.64E-07	8.54E-07
7.0E+01	2.58E-08*	1.90E-07	3.47E-07	5.19E-07	7.89E-07	8.64E-07	8.54E-07
1.0E+02	2.61E-08*	1.90E-07	3.47E-07	5.19E-07	7.89E-07	8.64E-07	8.54E-07
2.0E+02	2.68E-08*	1.90E-07	3.47E-07	5.19E-07	7.89E-07	8.64E-07	8.54E-07
4.0E+02	2.80E-08*	1.90E-07	3.47E-07	5.19E-07	7.89E-07	8.64E-07	8.54E-07
7.0E+02	2.93E-08*	1.91E-07	3.47E-07	5.19E-07	7.89E-07	8.64E-07	8.54E-07
1.0E+03	3.03E-08*	1.91E-07	3.47E-07	5.20E-07	7.89E-07	8.64E-07	8.54E-07
2.0E+03	3.33E-08*	1.92E-07	3.48E-07	5.20E-07	7.89E-07	8.65E-07	8.54E-07
4.0E+03	3.78E-08*	1.94E-07	3.48E-07	5.21E-07	7.89E-07	8.65E-07	8.54E-07
7.0E+03	4.35E-08*	1.98E-07	3.50E-07	5.22E-07	7.89E-07	8.64E-07	8.54E-07
1.0E+04	4.85E-08*	2.01E-07	3.51E-07	5.22E-07	7.89E-07	8.63E-07	8.52E-07
2.0E+04	6.30E-08*	2.10E-07	3.55E-07	5.24E-07	7.88E-07	8.64E-07	8.53E-07

Accuracy: * - Possible Error Greater Than 10%
** - Possible Error Greater Than 100%

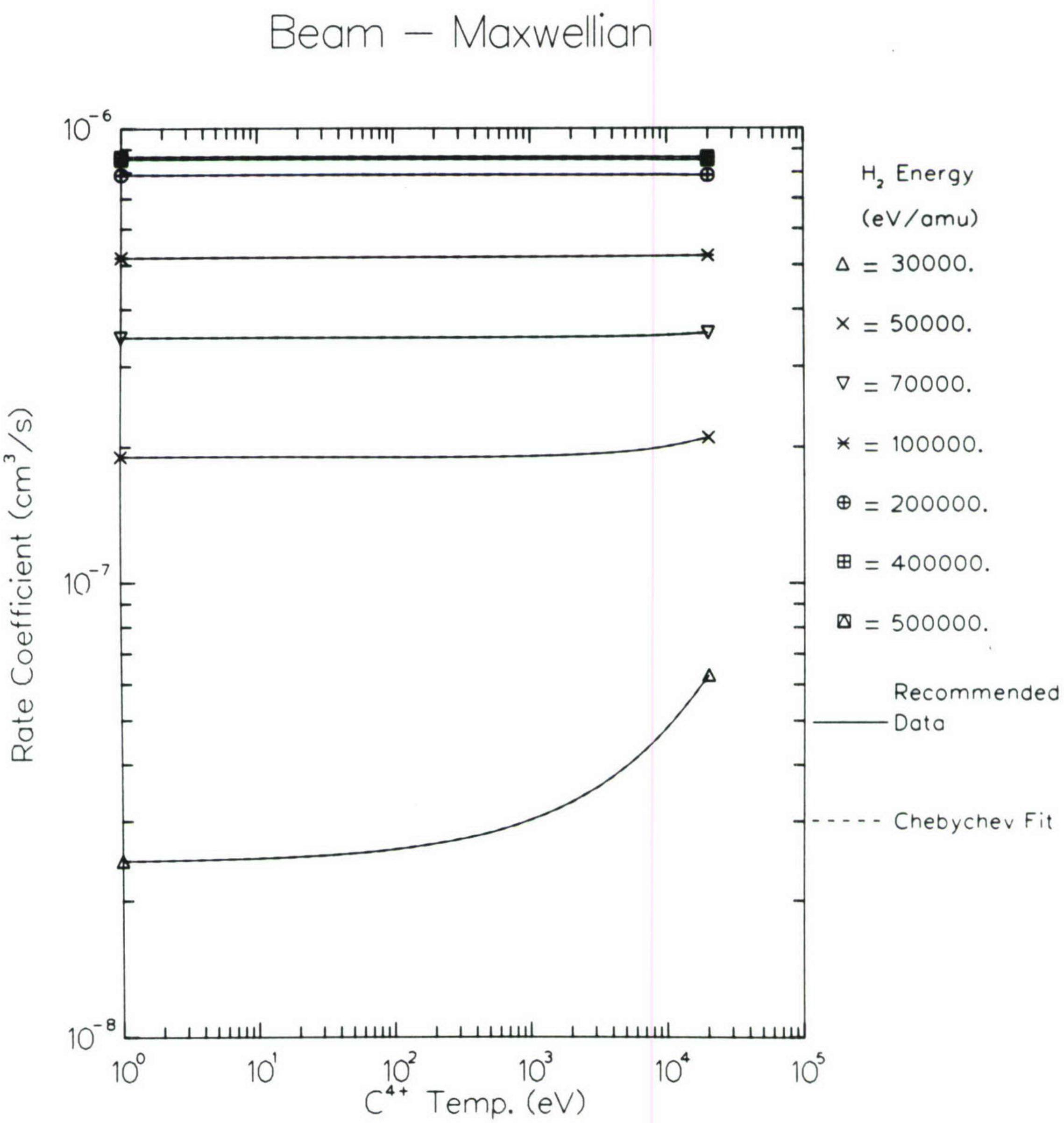
Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

Chebychev Fitting Parameters for Rate Coefficients

H_2 Energy (eV/amu)	C1	C2	C3	C4	C5	C6	C7
30000.	6.700E-08	1.476E-08	8.493E-09	3.929E-09	1.566E-09	5.481E-10	1.607E-10
50000.	3.875E-07	6.770E-09	4.754E-09	2.691E-09	1.231E-09	4.483E-10	1.246E-10
70000.	6.964E-07	2.839E-09	1.951E-09	1.106E-09	5.480E-10	2.264E-10	9.199E-11
100000.	1.040E-06	2.240E-09	1.056E-09	3.628E-10	1.110E-10	4.554E-11	3.547E-11
200000.	1.578E-06	-9.301E-11	-3.362E-10	-3.563E-10	-2.391E-10	-1.278E-10	-7.984E-11
400000.	1.728E-06	-1.144E-10	-2.136E-10	-1.487E-10	-4.355E-11	3.393E-11	9.014E-11
500000.	1.708E-06	-7.027E-10	-5.139E-10	-2.079E-10	1.652E-11	1.332E-10	2.219E-10

See appendix for Chebychev fit details.

$H_2 + C^{4+} \rightarrow C^{4+} + H_2^{+} + e^{-}$



Ionization Cross Sections for
$C^{5+} + H_2 \rightarrow C^{5+} + H_2^+ + e^-$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
3.0E+04	2.41E+08	1.94E-16
4.0E+04	2.78E+08	3.92E-16
7.0E+04	3.68E+08	1.15E-15
1.0E+05	4.39E+08	1.60E-15
1.7E+05	5.73E+08	1.89E-15
2.0E+05	6.21E+08	1.86E-15
4.0E+05	8.78E+08	1.51E-15
7.0E+05	1.16E+09	1.07E-15
1.0E+06	1.39E+09	8.33E-16
2.0E+06	1.96E+09	4.97E-16
4.0E+06	2.77E+09	2.87E-16
7.0E+06	3.65E+09	1.78E-16
1.0E+07	4.36E+09	1.31E-16

References: E.71, T.60

Accuracy: 30% for $E < 2\times10^5$ eV/amu; 20% for $E \geq 2\times10^5$ eV/amu

Notes: (1) The recommended cross section has been constructed on the basis of the semi-empirical scaling [T.60], normalized to the measurement at $E = 1.1\times10^6$ eV/amu [E.71], and to the empirical scaling relations for E_m (the energy at which the cross section maximum appears) and $\sigma(E_m)$, (see sect. 2.1.1).
(2) The recommended cross section represents the non-dissociative ionization channel only (producing H_2^+), as do the calculated reaction rate coefficients.

For Chebychev fits of the above cross sections it is necessary to use the following parameters.
E_{min} = 3.0E+04 eV/amu, E_{max} = 1.0E+07 eV/amu

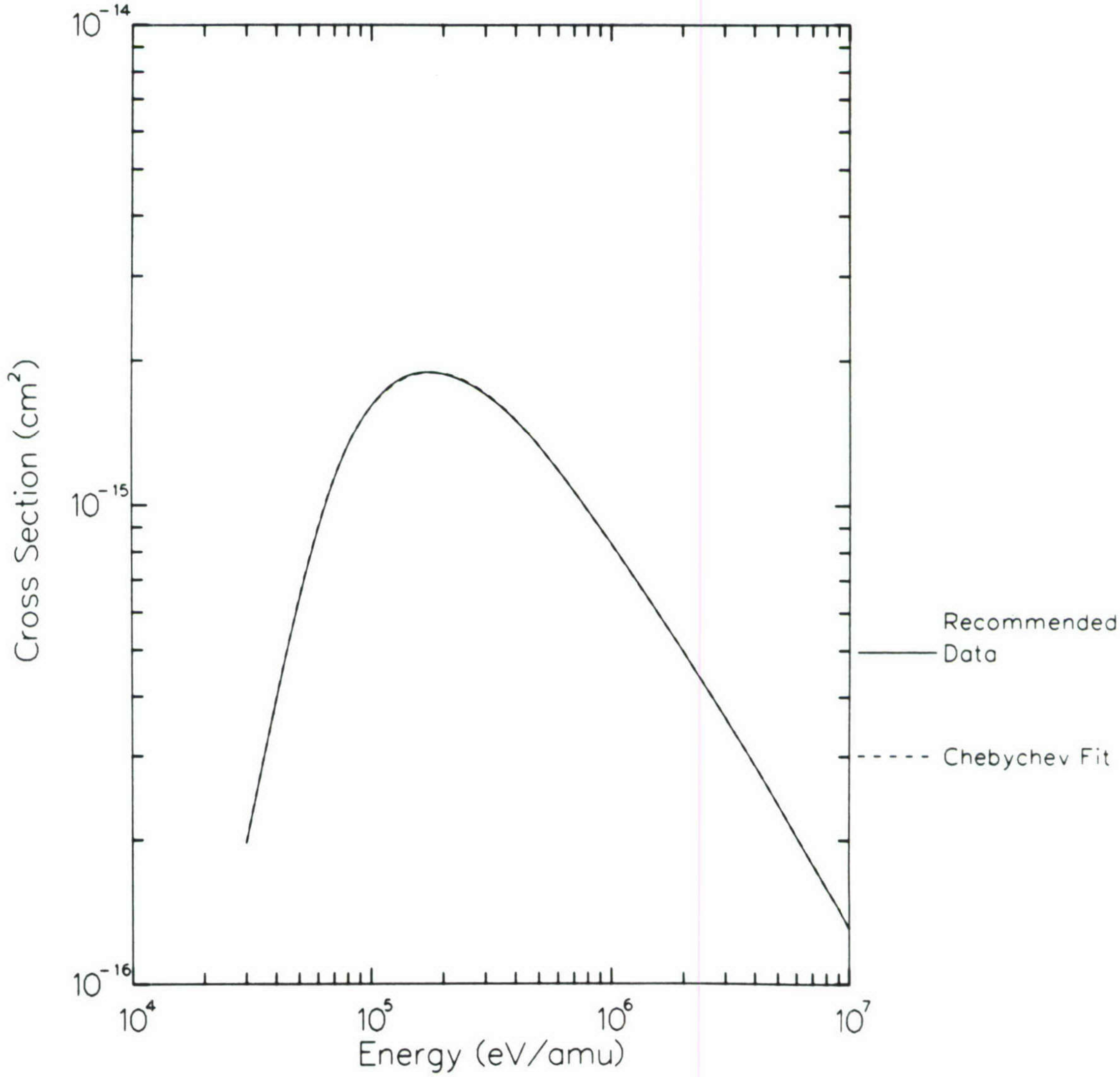
Chebychev Fitting Parameters for Cross Sections

C1	C2	C3	C4	C5	C6	C7	C8	C9
1.448E-15	-3.287E-16	-6.224E-16	4.366E-16	-1.651E-18	-1.376E-16	7.240E-17	-1.835E-18	-1.003E-17

The fit represents the above cross sections with an rms deviation of 0.4%.
The maximum deviation is 0.7% at 2.0E+05 eV/amu.
See appendix for Chebychev fit details.

$$C^{5+} + H_2 \rightarrow C^{5+} + H_2^{+} + e^{-}$$

Cross Section vs. Energy



Ionization Rate Coefficients for

$H_2 + C^{5+} \rightarrow C^{5+} + H_2^+ + e^-$

Beam - Maxwellian Rate Coefficients (cm^3/s)

C^{5+} Temp. (eV)	H_2 Energy (eV/amu) 30000.	50000.	70000.	100000.	200000.	400000.	500000.
1.0E+00	2.35E-08**	1.96E-07	4.23E-07	7.03E-07	1.16E-06	1.33E-06	1.32E-06
2.0E+00	2.36E-08**	1.96E-07	4.23E-07	7.03E-07	1.16E-06	1.33E-06	1.32E-06
4.0E+00	2.37E-08**	1.96E-07	4.23E-07	7.03E-07	1.16E-06	1.33E-06	1.32E-06
7.0E+00	2.38E-08*	1.96E-07	4.22E-07	7.03E-07	1.16E-06	1.33E-06	1.32E-06
1.0E+01	2.38E-08*	1.96E-07	4.22E-07	7.03E-07	1.16E-06	1.33E-06	1.32E-06
2.0E+01	2.41E-08*	1.96E-07	4.22E-07	7.03E-07	1.16E-06	1.33E-06	1.32E-06
4.0E+01	2.44E-08*	1.96E-07	4.22E-07	7.03E-07	1.16E-06	1.33E-06	1.32E-06
7.0E+01	2.47E-08*	1.96E-07	4.22E-07	7.03E-07	1.16E-06	1.33E-06	1.32E-06
1.0E+02	2.50E-08*	1.96E-07	4.22E-07	7.03E-07	1.16E-06	1.33E-06	1.32E-06
2.0E+02	2.57E-08*	1.96E-07	4.22E-07	7.04E-07	1.16E-06	1.33E-06	1.32E-06
4.0E+02	2.68E-08*	1.97E-07	4.22E-07	7.04E-07	1.16E-06	1.33E-06	1.32E-06
7.0E+02	2.80E-08*	1.97E-07	4.22E-07	7.04E-07	1.16E-06	1.33E-06	1.32E-06
1.0E+03	2.91E-08*	1.98E-07	4.22E-07	7.04E-07	1.16E-06	1.33E-06	1.32E-06
2.0E+03	3.19E-08*	2.00E-07	4.23E-07	7.05E-07	1.16E-06	1.33E-06	1.32E-06
4.0E+03	3.64E-08*	2.04E-07	4.24E-07	7.06E-07	1.16E-06	1.33E-06	1.32E-06
7.0E+03	4.21E-08*	2.10E-07	4.27E-07	7.07E-07	1.16E-06	1.32E-06	1.32E-06
1.0E+04	4.73E-08*	2.16E-07	4.30E-07	7.09E-07	1.16E-06	1.32E-06	1.31E-06
2.0E+04	6.31E-08*	2.33E-07	4.39E-07	7.11E-07	1.15E-06	1.32E-06	1.31E-06

Accuracy: * - Possible Error Greater Than 10%
** - Possible Error Greater Than 100%

Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

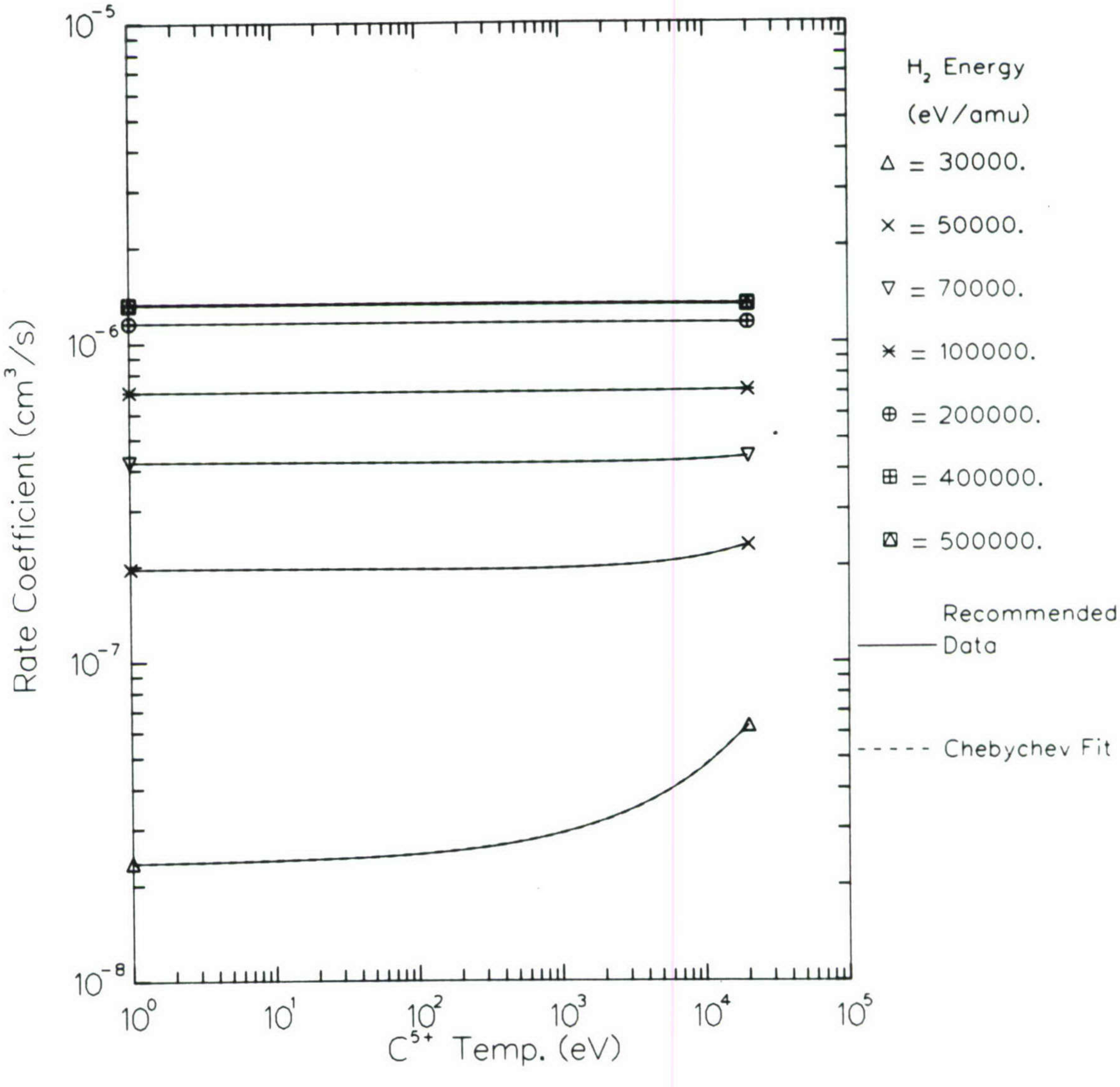
Chebychev Fitting Parameters for Rate Coefficients

H_2 Energy (eV/amu)	C1	C2	C3	C4	C5	C6	C7
30000.	6.497E-08	1.481E-08	8.722E-09	4.212E-09	1.788E-09	6.788E-10	2.206E-10
50000.	4.059E-07	1.245E-08	8.926E-09	4.943E-09	2.374E-09	7.922E-10	2.652E-10
70000.	8.502E-07	4.708E-09	4.377E-09	2.685E-09	1.561E-09	5.050E-10	2.596E-10
100000.	1.410E-06	3.332E-09	1.755E-09	6.973E-10	2.184E-10	4.811E-11	-5.388E-12
200000.	2.311E-06	-3.851E-10	-5.689E-10	-5.046E-10	-3.140E-10	-1.615E-10	-1.040E-10
400000.	2.651E-06	-1.271E-09	-8.760E-10	-4.269E-10	-1.219E-10	4.055E-11	1.372E-10
500000.	2.632E-06	-1.229E-09	-8.968E-10	-3.826E-10	-5.462E-12	1.923E-10	3.373E-10

See appendix for Chebychev fit details.

$H_2 + C^{5+} -> C^{5+} + H_2^+ + e^-$

Beam – Maxwellian



Ionization Cross Sections for
$C^{6+} + H_2 \to C^{6+} + H_2^+ + e^-$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
3.0E+04	2.41E+08	8.03E-17
4.0E+04	2.78E+08	2.60E-16
7.0E+04	3.68E+08	1.06E-15
1.0E+05	4.39E+08	1.65E-15
2.0E+05	6.21E+08	2.28E-15
4.0E+05	8.78E+08	1.90E-15
7.0E+05	1.16E+09	1.43E-15
1.0E+06	1.39E+09	1.15E-15
2.0E+06	1.96E+09	6.98E-16
4.0E+06	2.77E+09	4.03E-16
7.0E+06	3.65E+09	2.53E-16
1.0E+07	4.36E+09	1.86E-16

References: E.71, T.57, T.60

Accuracy: 30% for $E < 3 \times 10^5$ eV/amu; 20% for $E \geq 3 \times 10^5$ eV/amu

Notes: (1) The recommended cross section represents the non-dissociative ionization channel, as do the calculated reaction rate coefficients.
(2) The cross section has been constructed by using the semi-empirical scaling [T.60], normalized to the measurement at $E = 1.1 \times 10^6$ eV/amu [E.71], and to the value of the maximum cross section which follows from the empirical scaling of $C^{q+} + H_2$ (q = 2-4) data (see sect. 2.1.1).

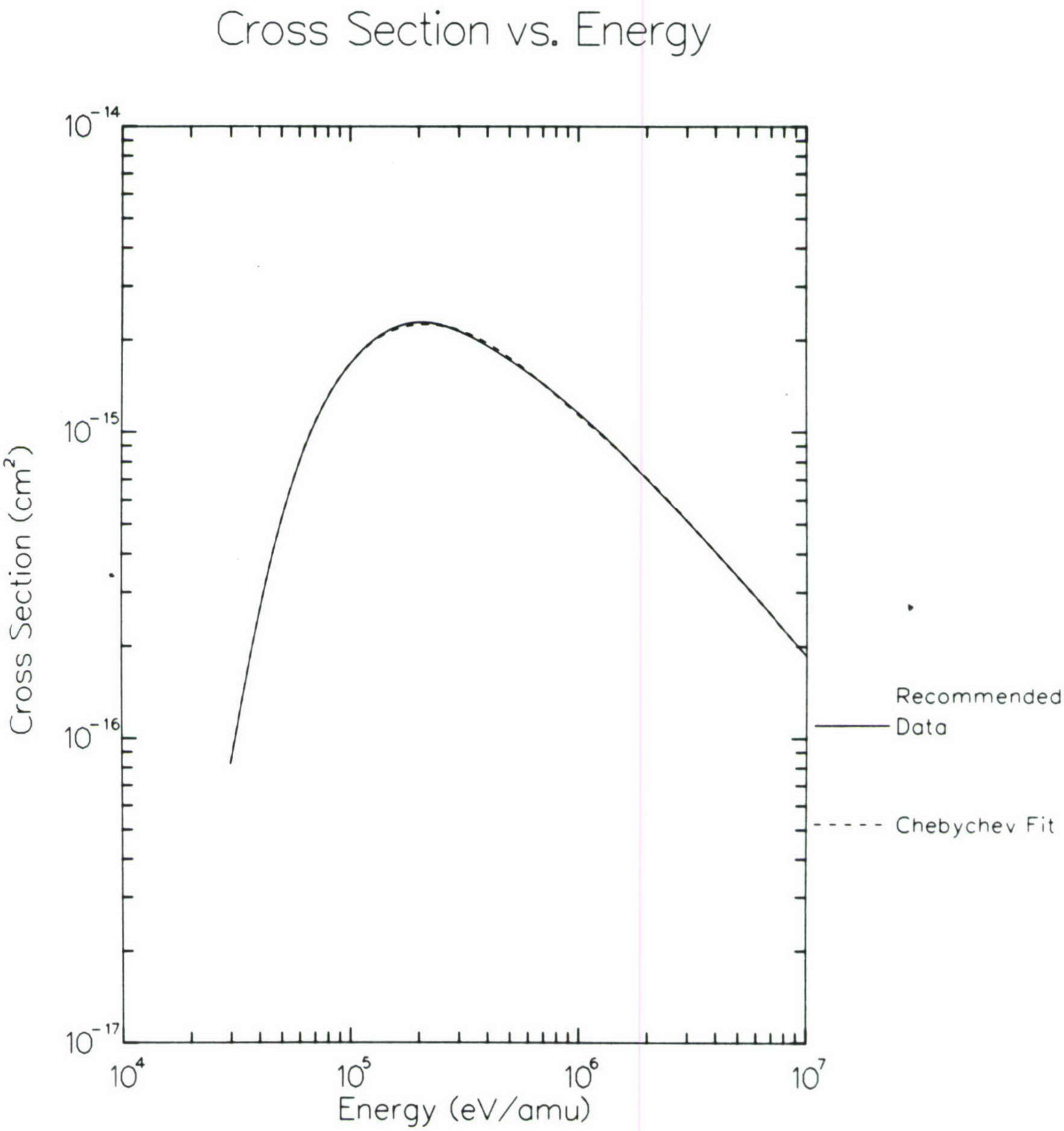
For Chebychev fits of the above cross sections it is necessary to use the following parameters.
E_{min} = 3.0E+04 eV/amu, E_{max} = 1.0E+07 eV/amu

Chebychev Fitting Parameters for Cross Sections

C1	C2	C3	C4	C5	C6	C7	C8	C9
1.672E-15	-2.372E-16	-8.374E-16	4.646E-16	8.603E-17	-1.936E-16	7.443E-17	1.901E-17	-2.598E-17

The fit represents the above cross sections with an rms deviation of 1.0%.
The maximum deviation is 2.3% at 4.0E+05 eV/amu.
See appendix for Chebychev fit details.

$C^{6+} + H_2 \rightarrow C^{6+} + H_2^+ + e^-$



Ionization Rate Coefficients for
$H_2 + C^{6+} \rightarrow C^{6+} + H_2^+ + e^-$

Beam - Maxwellian Rate Coefficients (cm^3/s)

C^{6+} Temp. (eV)	H_2 Energy (eV/amu) 30000.	50000.	70000.	100000.	200000.	400000.	500000.
1.0E+00	9.76E-09**	1.66E-07	3.90E-07	7.33E-07	1.42E-06	1.67E-06	1.69E-06
2.0E+00	9.81E-09**	1.63E-07	3.90E-07	7.25E-07	1.42E-06	1.67E-06	1.69E-06
4.0E+00	9.87E-09**	1.63E-07	3.90E-07	7.25E-07	1.42E-06	1.67E-06	1.69E-06
7.0E+00	9.93E-09*	1.63E-07	3.90E-07	7.25E-07	1.42E-06	1.67E-06	1.69E-06
1.0E+01	9.99E-09*	1.63E-07	3.90E-07	7.25E-07	1.42E-06	1.67E-06	1.69E-06
2.0E+01	1.01E-08*	1.63E-07	3.90E-07	7.25E-07	1.42E-06	1.67E-06	1.69E-06
4.0E+01	1.03E-08*	1.63E-07	3.90E-07	7.25E-07	1.42E-06	1.67E-06	1.69E-06
7.0E+01	1.06E-08*	1.63E-07	3.90E-07	7.25E-07	1.42E-06	1.67E-06	1.69E-06
1.0E+02	1.08E-08*	1.63E-07	3.90E-07	7.26E-07	1.42E-06	1.67E-06	1.69E-06
2.0E+02	1.12E-08*	1.63E-07	3.91E-07	7.26E-07	1.42E-06	1.67E-06	1.69E-06
4.0E+02	1.20E-08*	1.63E-07	3.91E-07	7.27E-07	1.42E-06	1.67E-06	1.69E-06
7.0E+02	1.29E-08*	1.64E-07	3.92E-07	7.27E-07	1.42E-06	1.67E-06	1.69E-06
1.0E+03	1.36E-08*	1.65E-07	3.93E-07	7.28E-07	1.42E-06	1.67E-06	1.69E-06
2.0E+03	1.58E-08*	1.67E-07	3.95E-07	7.29E-07	1.42E-06	1.67E-06	1.69E-06
4.0E+03	1.95E-08*	1.71E-07	3.98E-07	7.32E-07	1.42E-06	1.67E-06	1.69E-06
7.0E+03	2.44E-08*	1.77E-07	4.03E-07	7.34E-07	1.42E-06	1.68E-06	1.69E-06
1.0E+04	2.91E-08*	1.84E-07	4.07E-07	7.37E-07	1.42E-06	1.67E-06	1.69E-06
2.0E+04	4.41E-08*	2.03E-07	4.21E-07	7.45E-07	1.42E-06	1.68E-06	1.69E-06

Accuracy: * - Possible Error Greater Than 10%
** - Possible Error Greater Than 100%

Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

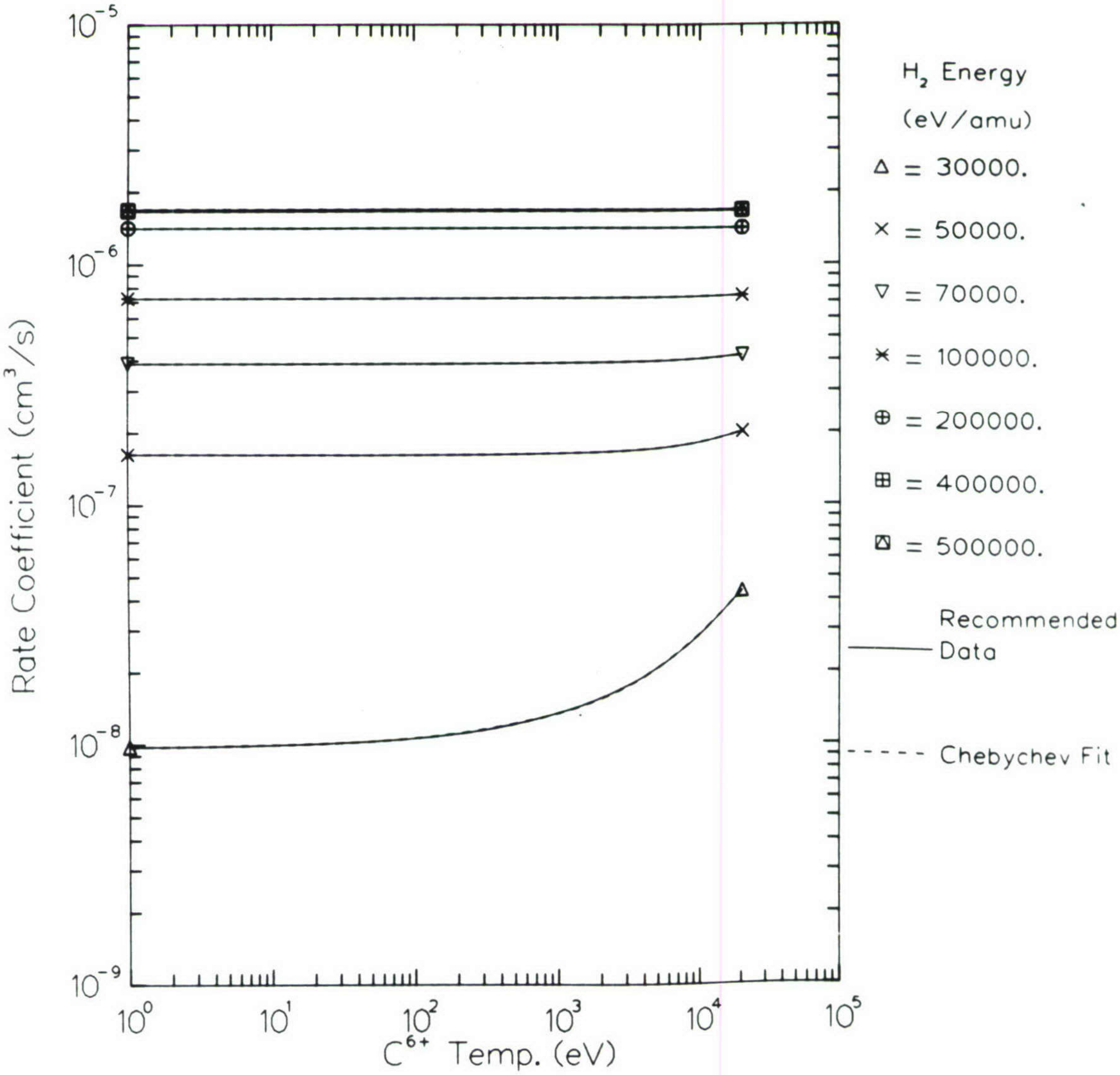
Chebychev Fitting Parameters for Rate Coefficients

H_2 Energy (eV/amu)	C1	C2	C3	C4	C5	C6	C7
30000.	3.414E-08	1.229E-08	7.671E-09	3.996E-09	1.822E-09	7.224E-10	2.289E-10
50000.	3.412E-07	1.276E-08	1.025E-08	4.837E-09	3.072E-09	5.991E-10	6.045E-10
70000.	7.922E-07	1.112E-08	7.200E-09	3.872E-09	1.787E-09	7.134E-10	2.547E-10
100000.	1.461E-06	5.997E-09	5.888E-09	8.149E-10	1.981E-09	-4.650E-10	7.548E-10
200000.	2.835E-06	1.436E-09	9.254E-11	-4.658E-10	-4.237E-10	-2.478E-10	-1.561E-10
400000.	3.343E-06	3.847E-09	1.516E-09	3.345E-10	4.762E-11	7.761E-11	1.717E-10
500000.	3.379E-06	-1.290E-09	-9.444E-10	-3.628E-10	6.313E-11	2.823E-10	4.538E-10

See appendix for Chebychev fit details.

$H_2 + C^{6+} -> C^{6+} + H_2^+ + e^-$

Beam – Maxwellian



Ionization Cross Sections for
$O^+ + H_2 \rightarrow O^+ + H_2^+ + e^-$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
1.7E+04	1.81E+08	6.64E-17
2.0E+04	1.96E+08	8.59E-17
4.0E+04	2.78E+08	2.09E-16
6.0E+04	3.40E+08	2.39E-16
7.0E+04	3.68E+08	2.36E-16
1.0E+05	4.39E+08	2.11E-16
2.0E+05	6.21E+08	1.46E-16
4.0E+05	8.78E+08	9.23E-17
7.0E+05	1.16E+09	5.97E-17
1.0E+06	1.39E+09	4.48E-17
2.0E+06	1.96E+09	2.40E-17
4.0E+06	2.77E+09	1.31E-17
7.0E+06	3.65E+09	7.94E-18
1.0E+07	4.36E+09	5.79E-18

References: T.60

Accuracy: 40% for $E < 4\times10^4$ eV/amu; 30% for $E \geq 4\times10^4$ eV/amu

Notes: (1) There are no experimental data available for this reaction.
(2) The recommended cross section represents the non-dissociative ionization channel, as do the calculated reaction rate coefficients.
(3) The recommended cross section has been constructed on the basis of the semi-empirical scaling [T.60] and by using the empirical scalings for E_m (the energy at which the cross section maximum occurs) and $\sigma(E_m)$ which follow from the experimental data for $O^{q+} + H_2$ (q = 2-4) [E.72], (see sect. 2.1.1).

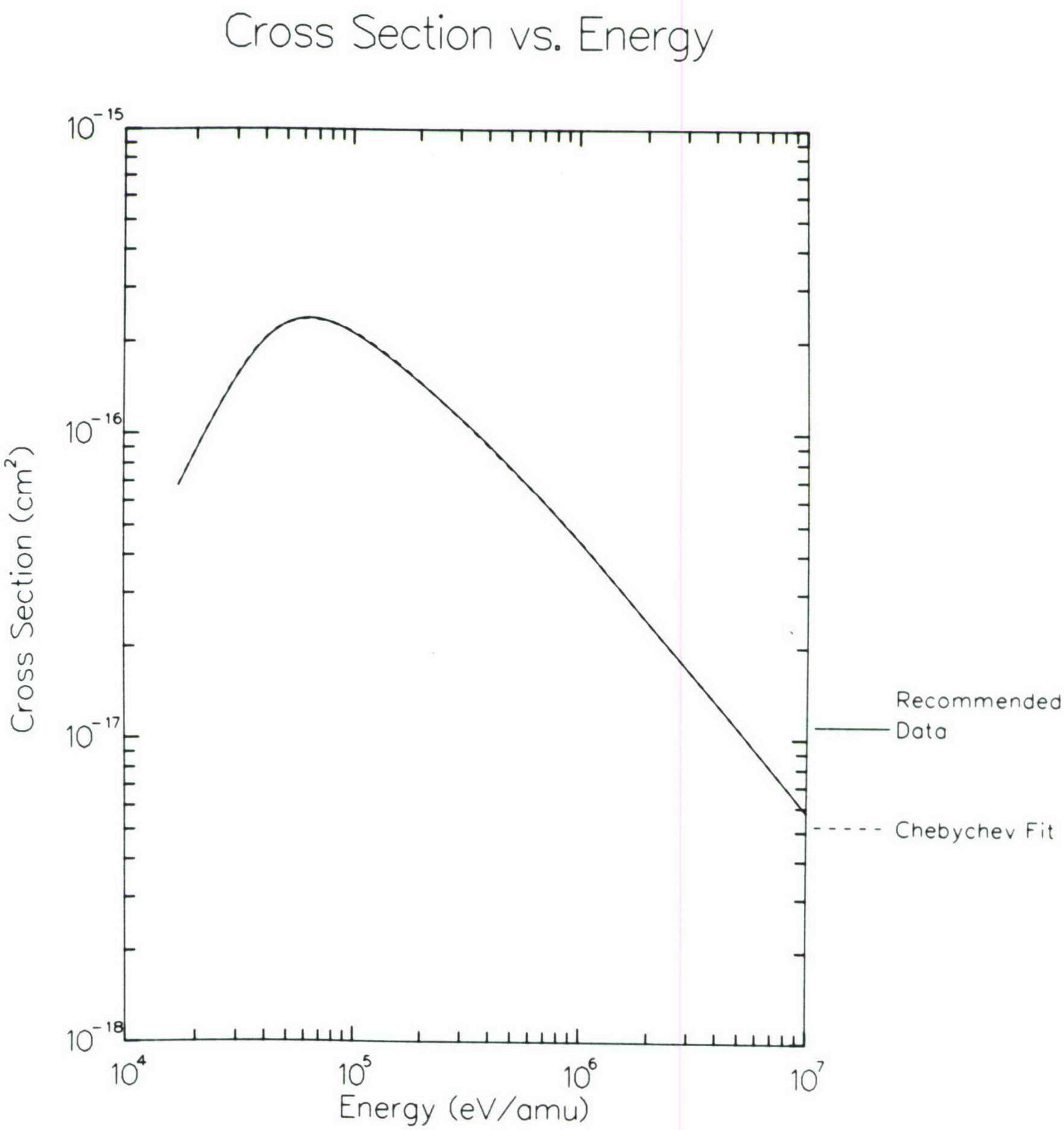
For Chebychev fits of the above cross sections it is necessary to use the following parameters.
E_{min} = 1.7E+04 eV/amu, E_{max} = 1.0E+07 eV/amu

Chebychev Fitting Parameters for Cross Sections

C1	C2	C3	C4	C5	C6	C7	C8	C9
1.736E-16	-8.105E-17	-3.490E-17	5.748E-17	-2.685E-17	1.094E-19	8.529E-18	-6.837E-18	2.535E-18

The fit represents the above cross sections with an rms deviation of 0.8%.
The maximum deviation is 1.3% at 1.0E+05 eV/amu.
See appendix for Chebychev fit details.

$O^+ + H_2 \rightarrow O^+ + H_2^+ + e^-$



Ionization Rate Coefficients for
$H_2 + O^+ \rightarrow O^+ + H_2^+ + e^-$

Beam - Maxwellian Rate Coefficients (cm^3/s)

O^+ Temp. (eV)	H_2 Energy (eV/amu) 20000.	30000.	50000.	70000.	100000.	200000.	500000.
1.0E+00	1.69E-08	3.62E-08	7.24E-08	8.67E-08	9.27E-08	9.07E-08	7.67E-08
2.0E+00	1.69E-08	3.62E-08	7.24E-08	8.67E-08	9.27E-08	9.07E-08	7.67E-08
4.0E+00	1.69E-08	3.62E-08	7.24E-08	8.67E-08	9.27E-08	9.07E-08	7.67E-08
7.0E+00	1.69E-08	3.62E-08	7.24E-08	8.67E-08	9.27E-08	9.07E-08	7.67E-08
1.0E+01	1.69E-08	3.62E-08	7.24E-08	8.67E-08	9.27E-08	9.07E-08	7.67E-08
2.0E+01	1.69E-08	3.62E-08	7.24E-08	8.67E-08	9.27E-08	9.07E-08	7.67E-08
4.0E+01	1.69E-08	3.62E-08	7.24E-08	8.67E-08	9.27E-08	9.07E-08	7.67E-08
7.0E+01	1.69E-08	3.62E-08	7.24E-08	8.67E-08	9.27E-08	9.07E-08	7.67E-08
1.0E+02	1.69E-08	3.63E-08	7.24E-08	8.67E-08	9.27E-08	9.07E-08	7.67E-08
2.0E+02	1.69E-08	3.63E-08	7.24E-08	8.67E-08	9.27E-08	9.07E-08	7.67E-08
4.0E+02	1.70E-08	3.63E-08	7.24E-08	8.67E-08	9.27E-08	9.07E-08	7.67E-08
7.0E+02	1.69E-08	3.64E-08	7.24E-08	8.67E-08	9.28E-08	9.07E-08	7.67E-08
1.0E+03	1.69E-08	3.65E-08	7.23E-08	8.67E-08	9.28E-08	9.07E-08	7.67E-08
2.0E+03	1.66E-08	3.67E-08	7.23E-08	8.66E-08	9.28E-08	9.08E-08	7.67E-08
4.0E+03	1.64E-08	3.72E-08	7.21E-08	8.66E-08	9.28E-08	9.08E-08	7.67E-08
7.0E+03	1.67E-08*	3.78E-08	7.18E-08	8.64E-08	9.27E-08	9.07E-08	7.67E-08
1.0E+04	1.72E-08*	3.84E-08	7.18E-08	8.62E-08	9.27E-08	9.08E-08	7.66E-08
2.0E+04	1.94E-08*	3.96E-08	7.10E-08	8.57E-08	9.25E-08	9.08E-08	7.67E-08

Accuracy: * - Possible Error Greater Than 10%
** - Possible Error Greater Than 100%

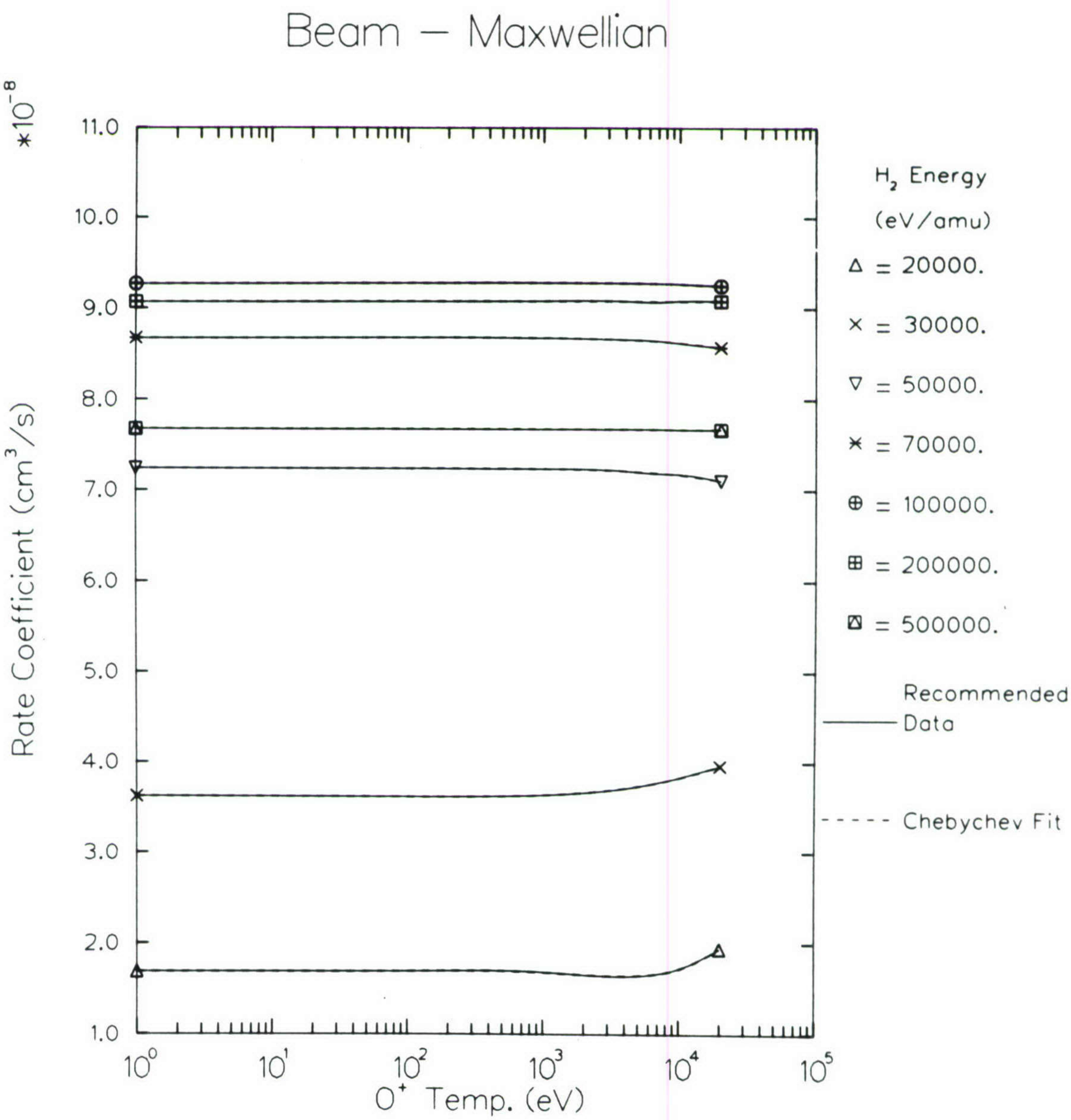
Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

Chebychev Fitting Parameters for Rate Coefficients

H_2 Energy (eV/amu)	C1	C2	C3	C4	C5	C6	C7
20000.	3.423E-08	4.865E-10	4.945E-10	5.024E-10	4.346E-10	2.825E-10	1.062E-10
30000.	7.390E-08	1.260E-09	8.507E-10	4.316E-10	1.535E-10	2.456E-11	-1.623E-11
50000.	1.443E-07	-4.481E-10	-3.205E-10	-1.878E-10	-9.017E-11	-3.504E-11	-1.180E-11
70000.	1.731E-07	-3.323E-10	-2.559E-10	-1.543E-10	-7.213E-11	-2.578E-11	-5.272E-12
100000.	1.854E-07	-2.380E-11	-6.158E-11	-5.914E-11	-3.622E-11	-1.627E-11	-5.579E-12
200000.	1.815E-07	4.975E-11	1.045E-11	-1.640E-12	1.961E-12	6.123E-12	6.157E-12
500000.	1.534E-07	-2.133E-11	-1.554E-11	-7.442E-12	-1.477E-12	1.754E-12	3.994E-12

See appendix for Chebychev fit details.

$H_2 + O^+ \rightarrow O^+ + H_2^+ + e^-$



Ionization Cross Sections for
$O^{2+} + H_2 \rightarrow O^{2+} + H_2^+ + e^-$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
1.1E+04	1.46E+08	1.16E-16
2.0E+04	1.96E+08	2.18E-16
4.0E+04	2.78E+08	4.87E-16
7.0E+04	3.68E+08	5.75E-16
1.0E+05	4.39E+08	5.57E-16
2.0E+05	6.21E+08	4.50E-16
4.0E+05	8.78E+08	3.03E-16
7.0E+05	1.16E+09	2.02E-16
1.0E+06	1.39E+09	1.54E-16
2.0E+06	1.96E+09	8.70E-17
4.0E+06	2.77E+09	4.89E-17
7.0E+06	3.65E+09	2.99E-17
1.0E+07	4.36E+09	2.20E-17

References: E.70, T.60

Accuracy: 15% for $E \leq 1.5\times10^5$ eV/amu; 20% for $E > 1.5\times10^5$ eV/amu

Notes: (1) The recommended cross section (solid curve) represents the non-dissociative ionization channel. For $E \leq 1.5\times10^5$ eV/amu, it is based on the experimental data [E.70], and for $E > 1.5\times10^5$ eV/amu, it represents the results of the semi-empirical scaling formula [T.60] (see also sect. 2.1.1). In the present case the results provided by this formula in the region of the cross section maximum coincide with experimental data (down to $E = 7\times10^4$ eV/amu).

(2) The dotted curve in the figure is the measured total cross section for dissociative ionization [E.70] (accuracy 15%), (see sect. 2.1.3).

(3) The calculated reaction rate coefficients are for the non-dissociative channel only.

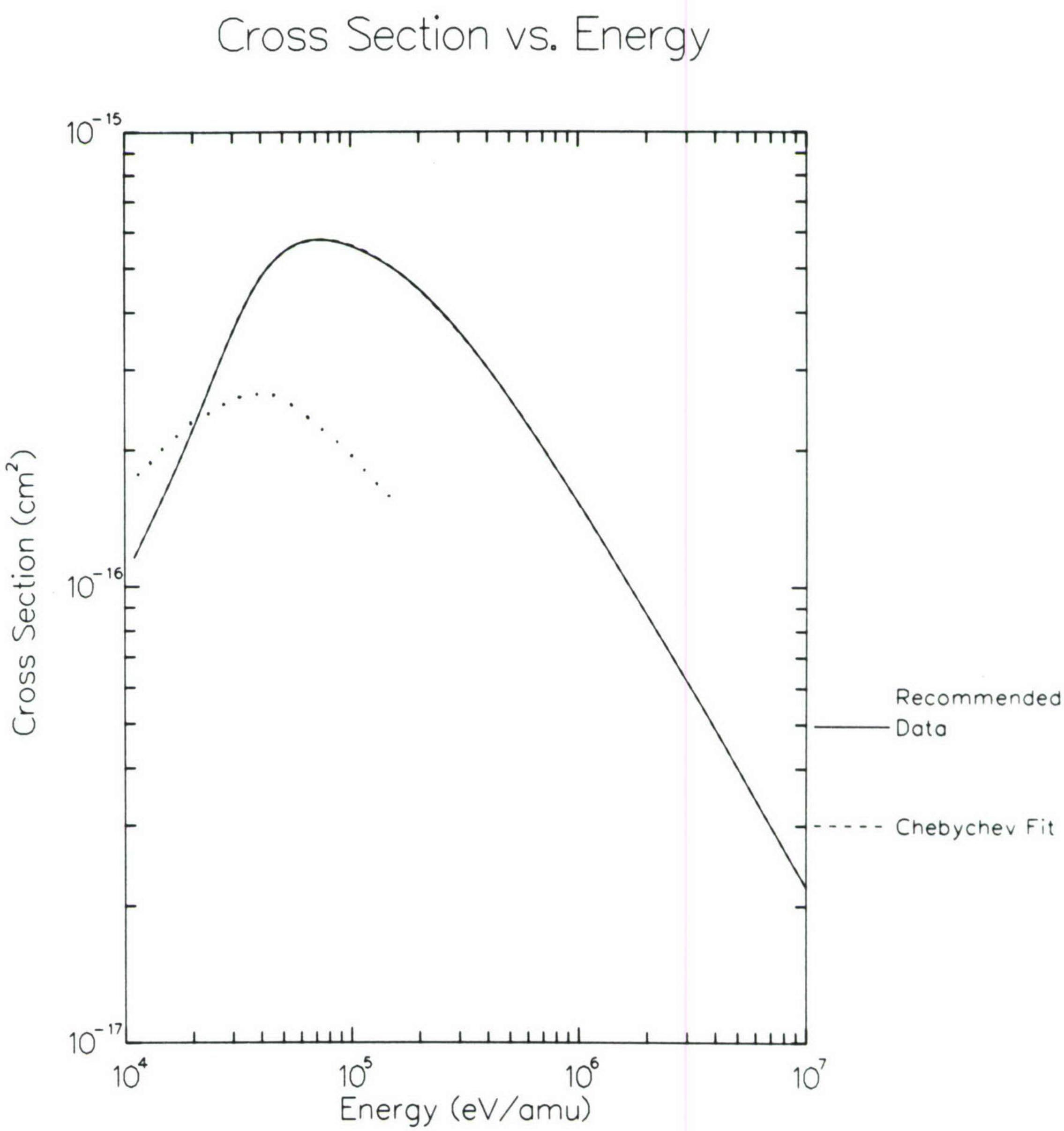
For Chebychev fits of the above cross sections it is necessary to use the following parameters.
E_{min} = 1.1E+04 eV/amu, E_{max} = 1.0E+07 eV/amu

Chebychev Fitting Parameters for Cross Sections

C1	C2	C3	C4	C5	C6	C7	C8	C9
4.211E-16	-1.315E-16	-1.677E-16	1.409E-16	-7.381E-18	-4.607E-17	3.171E-17	-1.032E-17	1.790E-18

The fit represents the above cross sections with an rms deviation of 0.3%.
The maximum deviation is 0.7% at 1.0E+05 eV/amu.
See appendix for Chebychev fit details.

$O^{2+} + H_2 \rightarrow O^{2+} + H_2^+ + e^-$



Ionization Rate Coefficients for
$H_2 + O^{2+} \rightarrow O^{2+} + H_2^+ + e^-$

Beam - Maxwellian Rate Coefficients (cm^3/s)

O^{2+} Temp. (eV)	H_2 Energy (eV/amu) 15000.	30000.	50000.	70000.	100000.	200000.	500000.
1.0E+00	2.72E-08	8.31E-08	1.70E-07	2.11E-07	2.45E-07	2.80E-07	2.55E-07
2.0E+00	2.72E-08	8.31E-08	1.70E-07	2.11E-07	2.45E-07	2.80E-07	2.55E-07
4.0E+00	2.72E-08	8.32E-08	1.70E-07	2.11E-07	2.45E-07	2.80E-07	2.55E-07
7.0E+00	2.72E-08	8.32E-08	1.70E-07	2.11E-07	2.45E-07	2.80E-07	2.55E-07
1.0E+01	2.72E-08	8.32E-08	1.70E-07	2.11E-07	2.45E-07	2.80E-07	2.55E-07
2.0E+01	2.72E-08	8.32E-08	1.70E-07	2.11E-07	2.45E-07	2.80E-07	2.55E-07
4.0E+01	2.72E-08	8.32E-08	1.70E-07	2.11E-07	2.45E-07	2.80E-07	2.55E-07
7.0E+01	2.72E-08	8.32E-08	1.70E-07	2.11E-07	2.45E-07	2.80E-07	2.55E-07
1.0E+02	2.72E-08	8.32E-08	1.70E-07	2.11E-07	2.45E-07	2.80E-07	2.55E-07
2.0E+02	2.73E-08	8.33E-08	1.70E-07	2.12E-07	2.45E-07	2.80E-07	2.55E-07
4.0E+02	2.73E-08	8.34E-08	1.70E-07	2.12E-07	2.45E-07	2.80E-07	2.55E-07
7.0E+02	2.74E-08	8.36E-08	1.70E-07	2.12E-07	2.45E-07	2.80E-07	2.55E-07
1.0E+03	2.76E-08	8.38E-08	1.70E-07	2.12E-07	2.45E-07	2.80E-07	2.55E-07
2.0E+03	2.78E-08	8.45E-08	1.70E-07	2.12E-07	2.45E-07	2.79E-07	2.55E-07
4.0E+03	2.80E-08	8.58E-08	1.70E-07	2.12E-07	2.45E-07	2.79E-07	2.55E-07
7.0E+03	2.86E-08	8.75E-08	1.70E-07	2.12E-07	2.45E-07	2.79E-07	2.55E-07
1.0E+04	2.94E-08	8.92E-08	1.70E-07	2.12E-07	2.45E-07	2.79E-07	2.55E-07
2.0E+04	3.30E-08	9.37E-08	1.69E-07	2.11E-07	2.45E-07	2.79E-07	2.55E-07

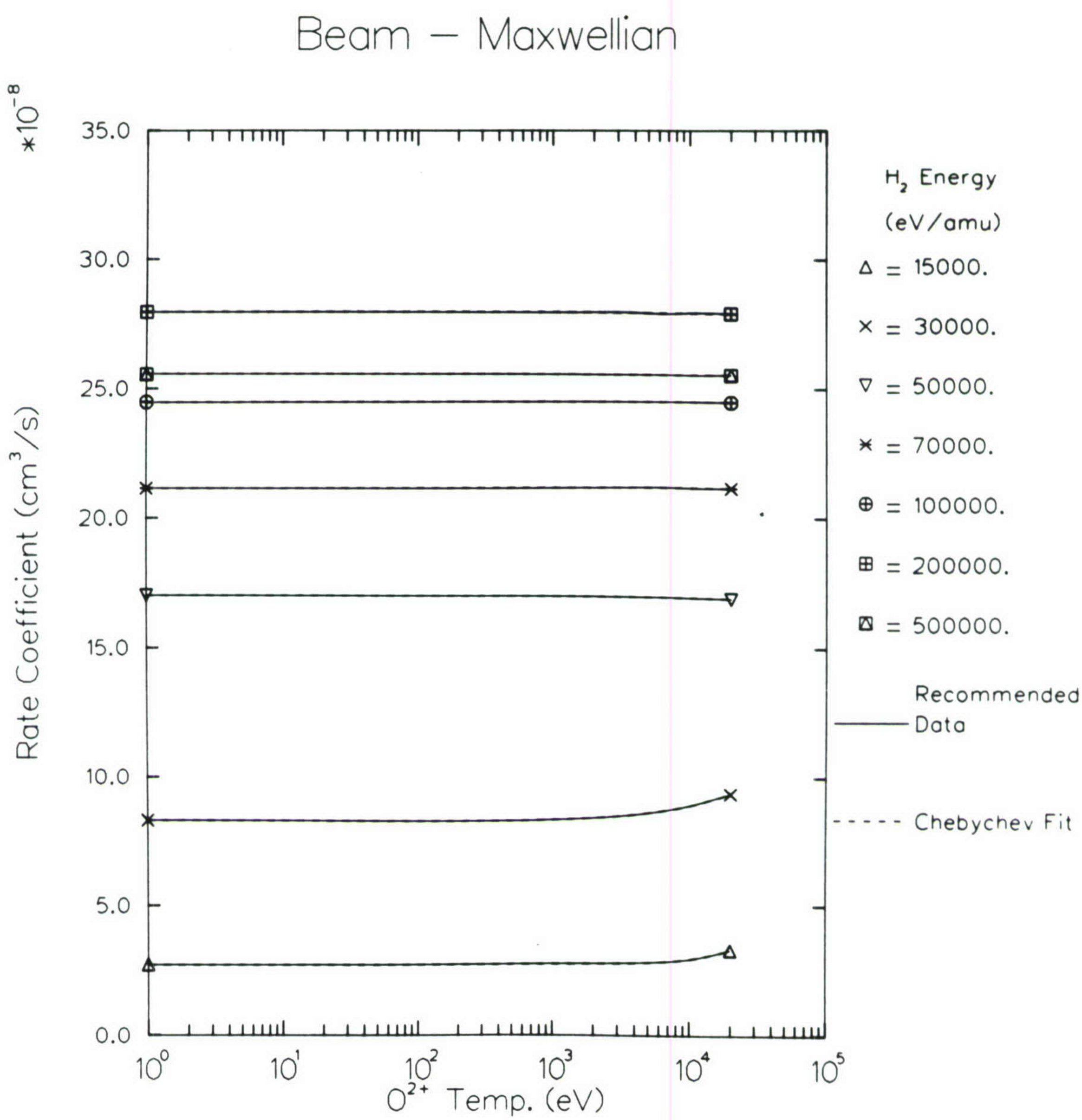
Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

Chebychev Fitting Parameters for Rate Coefficients

H_2 Energy (eV/amu)	C1	C2	C3	C4	C5	C6	C7
15000.	5.629E-08	1.750E-09	1.264E-09	8.279E-10	5.107E-10	3.016E-10	1.712E-10
30000.	1.705E-07	3.712E-09	2.562E-09	1.386E-09	5.783E-10	1.720E-10	2.191E-11
50000.	3.400E-07	-3.684E-10	-2.749E-10	-1.594E-10	-7.514E-11	-2.092E-11	2.370E-12
70000.	4.230E-07	2.089E-10	-4.718E-11	-1.163E-10	-7.540E-11	-2.745E-11	4.499E-13
100000.	4.895E-07	1.088E-10	-2.164E-11	-6.179E-11	-4.428E-11	-1.971E-11	-5.252E-12
200000.	5.588E-07	-1.938E-10	-1.446E-10	-7.039E-11	-1.271E-11	1.530E-11	1.866E-11
500000.	5.108E-07	-8.330E-11	-6.054E-11	-2.989E-11	-7.345E-12	4.927E-12	1.309E-11

See appendix for Chebychev fit details.

$H_2 + O^{2+} \rightarrow O^{2+} + H_2^+ + e^-$



Ionization Cross Sections for
$O^{3+} + H_2 \rightarrow O^{3+} + H_2^+ + e^-$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
1.4E+04	1.64E+08	1.17E-16
2.0E+04	1.96E+08	1.71E-16
4.0E+04	2.78E+08	5.12E-16
7.0E+04	3.68E+08	8.46E-16
1.0E+05	4.39E+08	9.17E-16
2.0E+05	6.21E+08	7.53E-16
4.0E+05	8.78E+08	5.26E-16
7.0E+05	1.16E+09	3.76E-16
1.0E+06	1.39E+09	2.97E-16
2.0E+06	1.96E+09	1.81E-16
4.0E+06	2.77E+09	1.03E-16
7.0E+06	3.65E+09	6.43E-17
1.0E+07	4.36E+09	4.81E-17

References: E.70, T.60

Accuracy: 15% for $E \leq 1.5\times10^5$ eV/amu; 20% for $E > 1.5\times10^5$ eV/amu

Notes: (1) The recommended cross section below 1.5×10^5 eV/amu represents the experimental data for non-dissociative ionization (producing H_2^+). At higher energies, the cross section is constructed using the semi-empirical scaling formula [T.60] (see also sect. 2.1.1), normalized to the experimental data from the region $7\times10^4 \leq E(\mathrm{eV/amu}) \leq 1.4\times10^5$, and preserving the Bethe-Born high-energy values (at $E \gtrsim 1\times10^7$ eV/amu).
(2) The dotted curve in the figure is the measured cross section for the dissociative ionization channel [E.70] (accuracy 15%), (see sect. 2.1.3).
(3) The calculated reaction rate coefficients are for non-dissociative ionization.

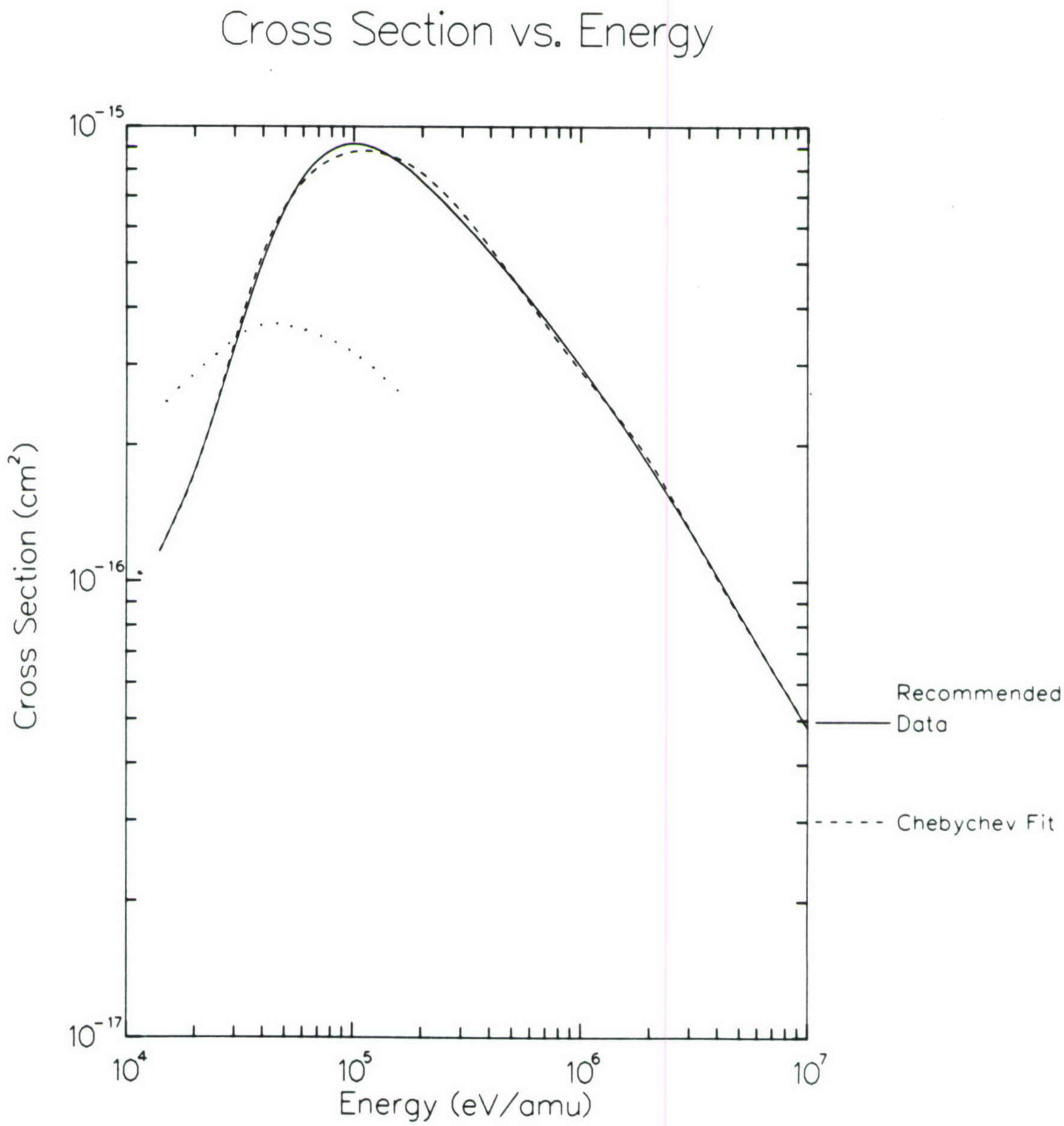
For Chebychev fits of the above cross sections it is necessary to use the following parameters.
E_{min} = 1.4E+04 eV/amu, E_{max} = 1.0E+07 eV/amu

Chebychev Fitting Parameters for Cross Sections

C1	C2	C3	C4	C5	C6	C7	C8	C9
6.407E-16	-1.542E-16	-2.839E-16	1.974E-16	1.511E-17	-8.277E-17	4.338E-17	4.964E-18	-1.232E-17

The fit represents the above cross sections with an rms deviation of 2.8%.
The maximum deviation is 4.4% at 2.0E+05 eV/amu.
See appendix for Chebychev fit details.

$O^{3+} + H_2 \rightarrow O^{3+} + H_2^+ + e^-$



Ionization Rate Coefficients for
$H_2 + O^{3+} \rightarrow O^{3+} + H_2^+ + e^-$

Beam - Maxwellian Rate Coefficients (cm^3/s)

O^{3+} Temp. (eV)	H_2 Energy (eV/amu) 15000.	30000.	50000.	70000.	100000.	200000.	500000.
1.0E+00	2.12E-08	7.38E-08	2.02E-07	3.11E-07	4.03E-07	4.68E-07	4.54E-07
2.0E+00	2.12E-08	7.38E-08	2.02E-07	3.11E-07	4.03E-07	4.68E-07	4.54E-07
4.0E+00	2.12E-08	7.38E-08	2.02E-07	3.11E-07	4.03E-07	4.68E-07	4.54E-07
7.0E+00	2.12E-08	7.38E-08	2.02E-07	3.11E-07	4.03E-07	4.68E-07	4.54E-07
1.0E+01	2.12E-08	7.38E-08	2.02E-07	3.11E-07	4.03E-07	4.68E-07	4.54E-07
2.0E+01	2.12E-08	7.38E-08	2.02E-07	3.11E-07	4.03E-07	4.68E-07	4.54E-07
4.0E+01	2.12E-08	7.38E-08	2.02E-07	3.11E-07	4.03E-07	4.68E-07	4.54E-07
7.0E+01	2.12E-08	7.38E-08	2.02E-07	3.11E-07	4.03E-07	4.68E-07	4.54E-07
1.0E+02	2.11E-08	7.39E-08	2.02E-07	3.11E-07	4.03E-07	4.68E-07	4.54E-07
2.0E+02	2.04E-08	7.40E-08	2.03E-07	3.11E-07	4.03E-07	4.68E-07	4.54E-07
4.0E+02	1.92E-08*	7.42E-08	2.03E-07	3.11E-07	4.03E-07	4.68E-07	4.54E-07
7.0E+02	1.82E-08*	7.45E-08	2.03E-07	3.11E-07	4.03E-07	4.69E-07	4.54E-07
1.0E+03	1.77E-08*	7.48E-08	2.03E-07	3.10E-07	4.03E-07	4.69E-07	4.54E-07
2.0E+03	1.71E-08*	7.58E-08	2.03E-07	3.10E-07	4.03E-07	4.69E-07	4.54E-07
4.0E+03	1.73E-08*	7.79E-08	2.04E-07	3.10E-07	4.03E-07	4.69E-07	4.54E-07
7.0E+03	1.83E-08*	8.08E-08	2.05E-07	3.10E-07	4.03E-07	4.69E-07	4.54E-07
1.0E+04	1.95E-08*	8.35E-08	2.06E-07	3.09E-07	4.03E-07	4.70E-07	4.54E-07
2.0E+04	2.40E-08*	9.15E-08	2.10E-07	3.10E-07	4.02E-07	4.70E-07	4.54E-07

Accuracy: * - Possible Error Greater Than 10%
** - Possible Error Greater Than 100%

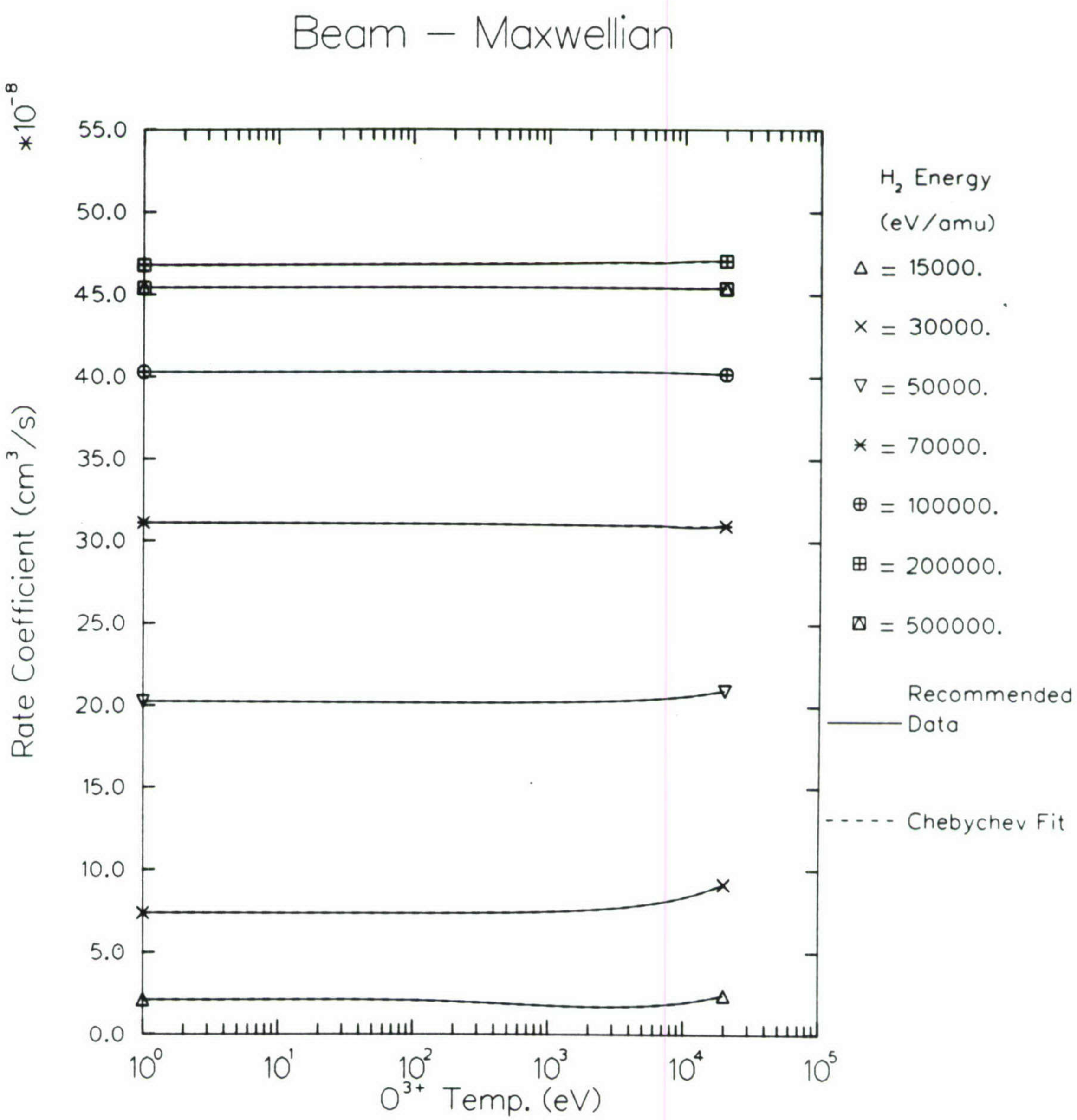
Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

Chebychev Fitting Parameters for Rate Coefficients

H_2 Energy (eV/amu)	C1	C2	C3	C4	C5	C6	C7
15000.	4.092E-08	-6.454E-10	1.088E-09	1.797E-09	1.168E-09	2.049E-10	-1.255E-10
30000.	1.545E-07	6.127E-09	4.286E-09	2.374E-09	1.048E-09	3.447E-10	7.444E-11
50000.	4.077E-07	2.567E-09	1.790E-09	1.005E-09	4.575E-10	1.698E-10	5.541E-11
70000.	6.209E-07	-6.498E-10	-2.796E-10	-2.100E-11	5.560E-11	8.149E-11	9.437E-11
100000.	8.055E-07	-1.934E-10	-3.269E-10	-2.862E-10	-1.676E-10	-7.253E-11	-2.354E-11
200000.	9.371E-07	1.186E-09	4.596E-10	9.561E-11	1.614E-11	2.381E-11	2.725E-11
500000.	9.079E-07	-9.698E-11	-7.110E-11	-3.133E-11	-2.032E-12	1.362E-11	2.545E-11

See appendix for Chebychev fit details.

$H_2 + O^{3+} \rightarrow O^{3+} + H_2^+ + e^-$



Ionization Cross Sections for
$O^{4+} + H_2 \rightarrow O^{4+} + H_2^+ + e^-$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
2.6E+04	2.24E+08	1.94E-16
4.0E+04	2.78E+08	4.63E-16
7.0E+04	3.68E+08	1.01E-15
1.0E+05	4.39E+08	1.22E-15
2.0E+05	6.21E+08	1.07E-15
4.0E+05	8.78E+08	7.70E-16
7.0E+05	1.16E+09	5.56E-16
1.0E+06	1.39E+09	4.45E-16
2.0E+06	1.96E+09	2.76E-16
4.0E+06	2.77E+09	1.64E-16
7.0E+06	3.65E+09	1.07E-16
1.0E+07	4.36E+09	8.24E-17

References: E.70, T.60

Accuracy: 15% for $E \leq 1.5 \times 10^5$ eV/amu; 20% for $E > 1.5 \times 10^5$ eV/amu

Notes: (1) The recommended cross section for non-dissociative ionization (solid curve) represents experimental data [E.70] for $E \lesssim 1.5 \times 10^5$ eV/amu. Above this energy, the cross section has been constructed by using the semi-empirical scaling formula [T.60] (see sect. 2.1.1), with normalization to the experiment in the region of cross section maximum and retaining the Bethe-Born values in the high-energy region ($E \gtrsim x10^7$ eV/amu).
(2) The dotted curve in the figure represents the experimental total cross section for dissociative ionization [E.70] (accuracy 15%), (see sect. 2.1.3).
(3) The calculated reaction rate coefficients are for non-dissociative ionization.

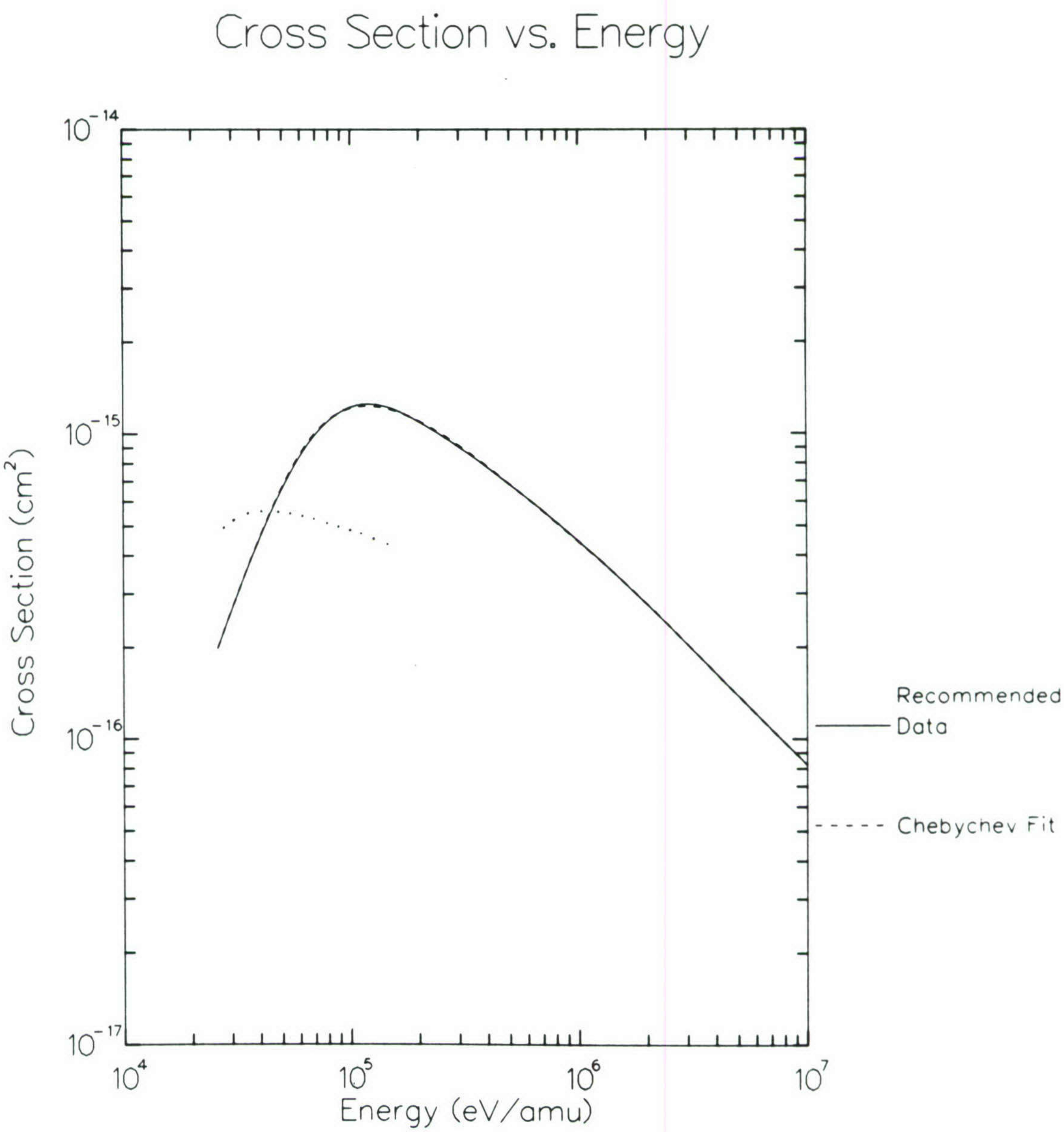
For Chebychev fits of the above cross sections it is necessary to use the following parameters.
E_{min} = 2.6E+04 eV/amu, E_{max} = 1.0E+07 eV/amu

Chebychev Fitting Parameters for Cross Sections

C1	C2	C3	C4	C5	C6	C7	C8	C9
9.387E-16	-2.700E-16	-3.336E-16	3.024E-16	-7.227E-17	-5.365E-17	6.702E-17	-3.467E-17	7.741E-18

The fit represents the above cross sections with an rms deviation of 1.4%.
The maximum deviation is 2.7% at 7.0E+04 eV/amu.
See appendix for Chebychev fit details.

$O^{4+} + H_2 \rightarrow O^{4+} + H_2^+ + e^-$



Ionization Rate Coefficients for
$H_2 + O^{4+} \rightarrow O^{4+} + H_2^+ + e^-$

Beam - Maxwellian Rate Coefficients (cm^3/s)

O^{4+} Temp. (eV)	H_2 Energy (eV/amu) 30000.	50000.	70000.	100000.	200000.	400000.	500000.
1.0E+00	6.40E-08	2.06E-07	3.70E-07	5.37E-07	6.65E-07	6.76E-07	6.68E-07
2.0E+00	6.40E-08	2.06E-07	3.71E-07	5.36E-07	6.65E-07	6.76E-07	6.68E-07
4.0E+00	6.40E-08	2.06E-07	3.71E-07	5.36E-07	6.65E-07	6.76E-07	6.68E-07
7.0E+00	6.40E-08	2.06E-07	3.71E-07	5.36E-07	6.65E-07	6.76E-07	6.68E-07
1.0E+01	6.40E-08	2.06E-07	3.71E-07	5.36E-07	6.65E-07	6.76E-07	6.68E-07
2.0E+01	6.40E-08	2.06E-07	3.71E-07	5.36E-07	6.65E-07	6.76E-07	6.68E-07
4.0E+01	6.40E-08	2.06E-07	3.71E-07	5.36E-07	6.65E-07	6.76E-07	6.68E-07
7.0E+01	6.40E-08	2.06E-07	3.71E-07	5.36E-07	6.65E-07	6.76E-07	6.68E-07
1.0E+02	6.40E-08	2.06E-07	3.71E-07	5.36E-07	6.65E-07	6.76E-07	6.68E-07
2.0E+02	6.41E-08	2.06E-07	3.71E-07	5.36E-07	6.65E-07	6.76E-07	6.68E-07
4.0E+02	6.43E-08	2.06E-07	3.71E-07	5.36E-07	6.66E-07	6.76E-07	6.68E-07
7.0E+02	6.44E-08	2.06E-07	3.71E-07	5.36E-07	6.66E-07	6.76E-07	6.68E-07
1.0E+03	6.43E-08	2.07E-07	3.71E-07	5.36E-07	6.66E-07	6.76E-07	6.68E-07
2.0E+03	6.35E-08	2.08E-07	3.70E-07	5.36E-07	6.67E-07	6.76E-07	6.68E-07
4.0E+03	6.30E-08	2.09E-07	3.71E-07	5.36E-07	6.67E-07	6.76E-07	6.68E-07
7.0E+03	6.42E-08*	2.12E-07	3.71E-07	5.35E-07	6.67E-07	6.76E-07	6.68E-07
1.0E+04	6.62E-08*	2.15E-07	3.72E-07	5.36E-07	6.68E-07	6.76E-07	6.68E-07
2.0E+04	7.47E-08*	2.23E-07	3.74E-07	5.34E-07	6.68E-07	6.76E-07	6.68E-07

Accuracy: * - Possible Error Greater Than 10%
** - Possible Error Greater Than 100%

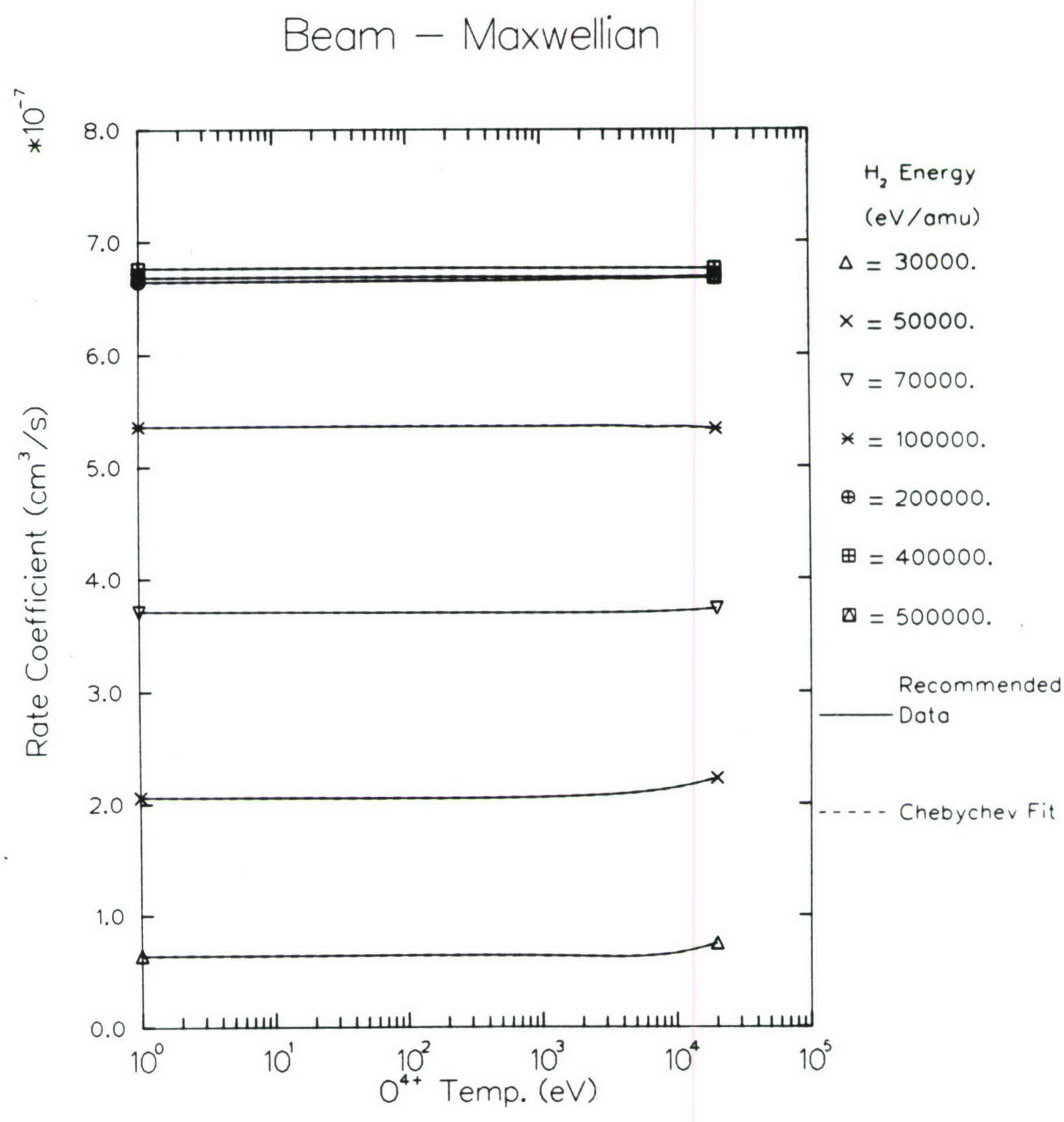
Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

Chebychev Fitting Parameters for Rate Coefficients

H_2 Energy (eV/amu)	C1	C2	C3	C4	C5	C6	C7
30000.	1.304E-07	2.434E-09	2.152E-09	1.914E-09	1.565E-09	1.021E-09	4.403E-10
50000.	4.182E-07	5.743E-09	4.161E-09	2.315E-09	1.150E-09	3.913E-10	1.480E-10
70000.	7.422E-07	7.514E-10	4.624E-10	8.643E-10	1.681E-10	3.049E-10	-5.848E-11
100000.	1.072E-06	-8.164E-10	-3.874E-10	-6.788E-10	-4.732E-11	-1.993E-10	9.874E-11
200000.	1.332E-06	1.760E-09	6.602E-10	1.150E-10	4.777E-12	2.417E-11	3.513E-11
400000.	1.353E-06	-7.552E-11	-6.011E-11	-5.341E-11	-1.276E-11	-6.393E-12	1.409E-11
500000.	1.336E-06	-1.613E-10	-1.180E-10	-5.399E-11	-6.866E-12	1.847E-11	3.695E-11

See appendix for Chebychev fit details.

$H_2 + O^{4+} -> O^{4+} + H_2^+ + e^-$


Beam – Maxwellian
*10^-7
Rate Coefficient (cm^3/s)
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
10^0
10^1
10^2
10^3
10^4
10^5
O^4+ Temp. (eV)
H2 Energy
(eV/amu)
Δ = 30000.
× = 50000.
∇ = 70000.
✱ = 100000.
⊕ = 200000.
⊞ = 400000.
⊠ = 500000.
Recommended Data
Chebychev Fit

Ionization Cross Sections for

$O^{5+} + H_2 \rightarrow O^{5+} + H_2^+ + e^-$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
2.9E+04	2.37E+08	2.64E-16
4.0E+04	2.78E+08	4.52E-16
7.0E+04	3.68E+08	1.10E-15
1.0E+05	4.39E+08	1.46E-15
2.0E+05	6.21E+08	1.48E-15
4.0E+05	8.78E+08	1.15E-15
7.0E+05	1.16E+09	8.60E-16
1.0E+06	1.39E+09	6.95E-16
2.0E+06	1.96E+09	4.35E-16
4.0E+06	2.77E+09	2.62E-16
7.0E+06	3.65E+09	1.70E-16
1.0E+07	4.36E+09	1.33E-16

References: E.70, T.60

Accuracy: 30% for $E < 7\times10^4$ eV/amu; 15% for $7\times10^4 \leq E$(eV/amu) $\leq 1.5\times10^5$; 25% for $E > 1.5\times10^5$ eV/amu

Notes: (1) The non-dissociative ionization cross section (solid curve) in the region $7\times10^4 \leq$ E(eV/amu) $\leq 1.5\times10^5$ represents the experimental data [E.70]. Outside this region, the cross section has been constructed on the basis of the semi-empirical scaling formula [T.60] with normalization to the experimental data, (see sect. 2.1.1 for details).
(2) The dotted curve in the figure is the measured total cross section for dissociative ionization [E.70] (accuracy 15%), (see sect. 2.1.3).
(3) The calculated reaction rate coefficients are for the non-dissociative ionization channel only.

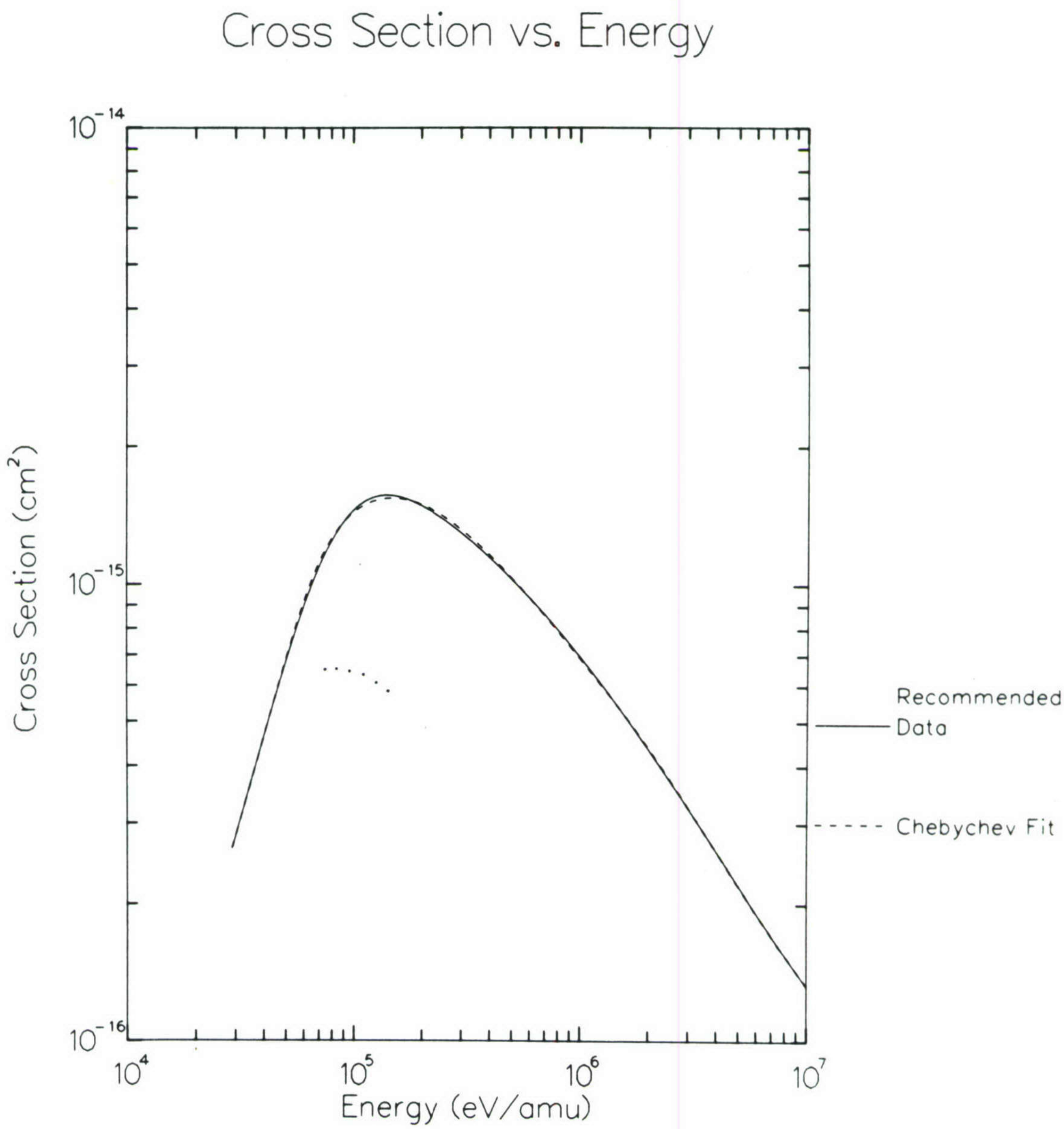
For Chebychev fits of the above cross sections it is necessary to use the following parameters.
E_{min} = 2.9E+04 eV/amu, E_{max} = 1.0E+07 eV/amu

Chebychev Fitting Parameters for Cross Sections

C1	C2	C3	C4	C5	C6	C7	C8	C9
1.271E-15	-3.114E-16	-4.679E-16	3.528E-16	-3.851E-17	-8.450E-17	6.908E-17	-2.246E-17	4.743E-19

The fit represents the above cross sections with an rms deviation of 1.3%.
The maximum deviation is 2.6% at 7.0E+04 eV/amu.
See appendix for Chebychev fit details.

$O^{5+} + H_2 \rightarrow O^{5+} + H_2^+ + e^-$



Ionization Rate Coefficients for
$H_2 + O^{5+} \rightarrow O^{5+} + H_2^+ + e^-$

Beam - Maxwellian Rate Coefficients (cm^3/s)

O^{5+} Temp. (eV)	H_2 Energy (eV/amu) 30000.	50000.	70000.	100000.	200000.	400000.	500000.
1.0E+00	6.77E-08	2.02E-07	4.04E-07	6.46E-07	9.19E-07	1.01E-06	1.02E-06
2.0E+00	6.73E-08	2.02E-07	4.04E-07	6.41E-07	9.19E-07	1.01E-06	1.02E-06
4.0E+00	6.73E-08	2.02E-07	4.04E-07	6.41E-07	9.19E-07	1.01E-06	1.02E-06
7.0E+00	6.73E-08	2.02E-07	4.04E-07	6.41E-07	9.19E-07	1.01E-06	1.02E-06
1.0E+01	6.73E-08	2.02E-07	4.04E-07	6.41E-07	9.19E-07	1.01E-06	1.02E-06
2.0E+01	6.73E-08	2.02E-07	4.04E-07	6.41E-07	9.19E-07	1.01E-06	1.02E-06
4.0E+01	6.70E-08	2.02E-07	4.04E-07	6.41E-07	9.20E-07	1.01E-06	1.02E-06
7.0E+01	6.59E-08	2.02E-07	4.04E-07	6.41E-07	9.20E-07	1.01E-06	1.02E-06
1.0E+02	6.44E-08	2.02E-07	4.03E-07	6.41E-07	9.20E-07	1.01E-06	1.02E-06
2.0E+02	6.02E-08*	2.02E-07	4.03E-07	6.41E-07	9.20E-07	1.01E-06	1.01E-06
4.0E+02	5.58E-08*	2.02E-07	4.03E-07	6.41E-07	9.20E-07	1.01E-06	1.01E-06
7.0E+02	5.29E-08*	2.03E-07	4.03E-07	6.41E-07	9.20E-07	1.01E-06	1.01E-06
1.0E+03	5.15E-08*	2.03E-07	4.02E-07	6.41E-07	9.20E-07	1.01E-06	1.01E-06
2.0E+03	5.04E-08*	2.04E-07	4.02E-07	6.41E-07	9.21E-07	1.01E-06	1.01E-06
4.0E+03	5.14E-08*	2.07E-07	4.03E-07	6.41E-07	9.21E-07	1.01E-06	1.01E-06
7.0E+03	5.43E-08*	2.11E-07	4.04E-07	6.41E-07	9.20E-07	1.01E-06	1.01E-06
1.0E+04	5.74E-08*	2.15E-07	4.05E-07	6.40E-07	9.21E-07	1.01E-06	1.01E-06
2.0E+04	6.77E-08*	2.27E-07	4.11E-07	6.40E-07	9.21E-07	1.01E-06	1.01E-06

Accuracy: * - Possible Error Greater Than 10%
** - Possible Error Greater Than 100%

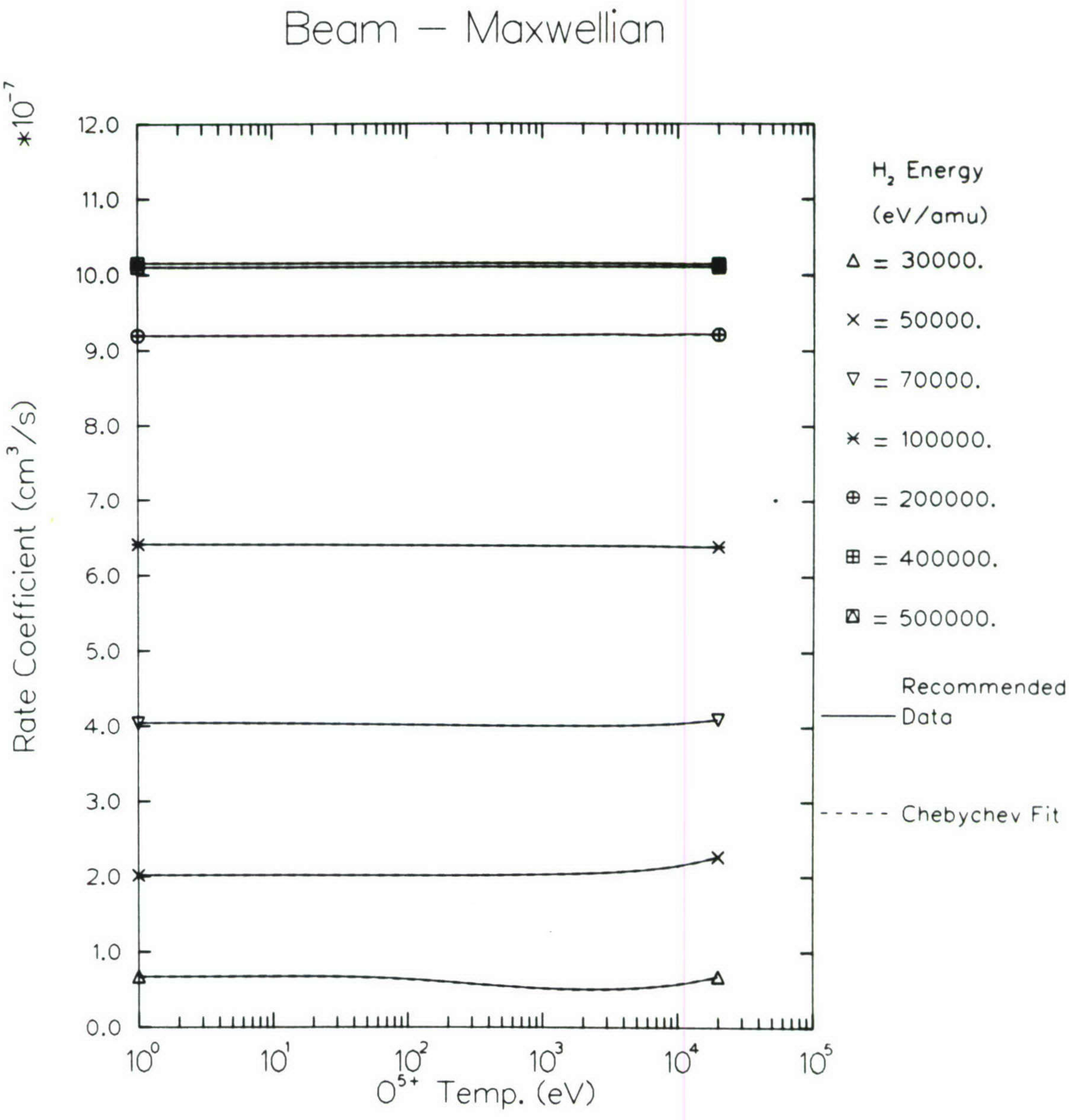
Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

Chebychev Fitting Parameters for Rate Coefficients

H_2 Energy (eV/amu)	C1	C2	C3	C4	C5	C6	C7
30000.	1.243E-07	-5.551E-09	3.037E-09	5.805E-09	2.750E-09	-4.741E-10	-3.332E-10
50000.	4.126E-07	8.439E-09	5.983E-09	3.426E-09	1.603E-09	5.919E-10	1.648E-10
70000.	8.089E-07	1.262E-09	1.961E-09	1.656E-09	9.406E-10	3.941E-10	1.283E-10
100000.	1.283E-06	-1.314E-09	4.297E-10	-9.301E-10	4.909E-10	-4.551E-10	3.715E-10
200000.	1.840E-06	9.130E-10	2.214E-10	-3.585E-11	-1.381E-11	4.642E-11	5.909E-11
400000.	2.020E-06	2.427E-10	6.691E-11	-3.574E-11	-1.592E-11	-1.102E-11	1.877E-11
500000.	2.030E-06	-2.863E-10	-2.087E-10	-9.909E-11	-1.845E-11	2.513E-11	5.560E-11

See appendix for Chebychev fit details.

$H_2 + O^{5+} \rightarrow O^{5+} + H_2^+ + e^-$



Ionization Cross Sections for
$O^{6+} + H_2 \rightarrow O^{6+} + H_2^+ + e^-$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
2.9E+04	2.37E+08	8.17E-17
4.0E+04	2.78E+08	2.07E-16
7.0E+04	3.68E+08	8.23E-16
1.0E+05	4.39E+08	1.42E-15
2.0E+05	6.21E+08	2.01E-15
4.0E+05	8.78E+08	1.66E-15
7.0E+05	1.16E+09	1.26E-15
1.0E+06	1.39E+09	1.02E-15
2.0E+06	1.96E+09	6.48E-16
4.0E+06	2.77E+09	3.91E-16
7.0E+06	3.65E+09	2.51E-16
1.0E+07	4.36E+09	1.87E-16

References: T.60

Accuracy: 50% for $E < 1.3 \times 10^5$ eV/amu; 30% for $E \geq 1.3 \times 10^5$ eV/amu

Notes: (1) There are no experimental data available for this reaction.
(2) The recommended cross section is for non-dissociative ionization, as are the calculated reaction rate coefficients.
(3) The cross section has been constructed on the basis of the semi-empirical scaling [T.60], normalized to the maximum cross section $\sigma(E_m)$, scaled empirically from the O^{q+} + H_2 (q = 2-5) experimental data, (see sect. 2.1.1 for details.).

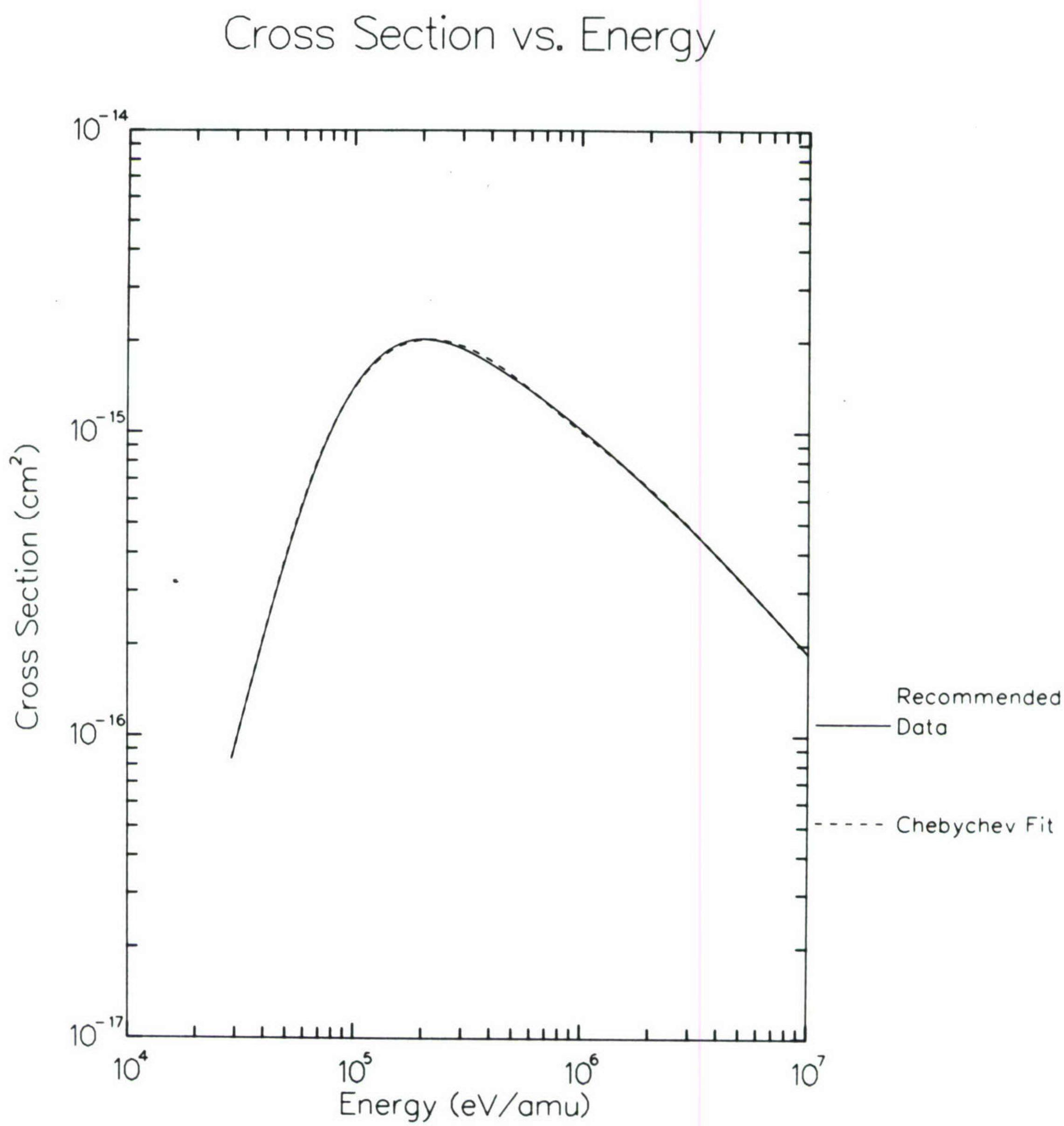
For Chebychev fits of the above cross sections it is necessary to use the following parameters.
E_{min} = 2.9E+04 eV/amu, E_{max} = 1.0E+07 eV/amu

Chebychev Fitting Parameters for Cross Sections

C1	C2	C3	C4	C5	C6	C7	C8	C9
1.469E-15	-1.626E-16	-7.437E-16	3.805E-16	1.109E-16	-2.020E-16	7.429E-17	3.667E-17	-4.161E-17

The fit represents the above cross sections with an rms deviation of 1.7%.
The maximum deviation is 4.1% at 4.0E+05 eV/amu.
See appendix for Chebychev fit details.

$O^{6+} + H_2 -> O^{6+} + H_2^+ + e^-$


Cross Section vs. Energy
10^{-14}
10^{-15}
10^{-16}
10^{-17}
Cross Section (cm^2)
10^4
10^5
10^6
10^7
Energy (eV/amu)
Recommended Data
Chebychev Fit

Ionization Rate Coefficients for
$H_2 + O^{6+} \rightarrow O^{6+} + H_2^+ + e^-$

Beam - Maxwellian Rate Coefficients (cm^3/s)

O^{6+} Temp. (eV)	H_2 Energy (eV/amu) 30000.	50000.	70000.	100000.	200000.	400000.	500000.
1.0E+00	2.18E-08	1.16E-07	3.02E-07	6.31E-07	1.25E-06	1.46E-06	1.48E-06
2.0E+00	2.18E-08	1.16E-07	3.02E-07	6.24E-07	1.25E-06	1.46E-06	1.48E-06
4.0E+00	2.18E-08	1.16E-07	3.02E-07	6.24E-07	1.25E-06	1.46E-06	1.48E-06
7.0E+00	2.18E-08	1.16E-07	3.02E-07	6.24E-07	1.25E-06	1.46E-06	1.48E-06
1.0E+01	2.18E-08	1.16E-07	3.02E-07	6.24E-07	1.25E-06	1.46E-06	1.48E-06
2.0E+01	2.18E-08	1.16E-07	3.02E-07	6.24E-07	1.25E-06	1.46E-06	1.48E-06
4.0E+01	2.17E-08	1.16E-07	3.02E-07	6.24E-07	1.25E-06	1.46E-06	1.48E-06
7.0E+01	2.14E-08	1.16E-07	3.02E-07	6.24E-07	1.25E-06	1.46E-06	1.48E-06
1.0E+02	2.09E-08	1.16E-07	3.02E-07	6.24E-07	1.25E-06	1.46E-06	1.48E-06
2.0E+02	1.97E-08*	1.16E-07	3.02E-07	6.24E-07	1.25E-06	1.46E-06	1.48E-06
4.0E+02	1.85E-08*	1.16E-07	3.02E-07	6.24E-07	1.25E-06	1.46E-06	1.48E-06
7.0E+02	1.78E-08*	1.17E-07	3.02E-07	6.24E-07	1.25E-06	1.46E-06	1.48E-06
1.0E+03	1.75E-08*	1.17E-07	3.03E-07	6.24E-07	1.25E-06	1.46E-06	1.48E-06
2.0E+03	1.77E-08*	1.18E-07	3.04E-07	6.25E-07	1.25E-06	1.46E-06	1.48E-06
4.0E+03	1.89E-08*	1.21E-07	3.06E-07	6.26E-07	1.25E-06	1.46E-06	1.48E-06
7.0E+03	2.10E-08*	1.25E-07	3.09E-07	6.28E-07	1.25E-06	1.46E-06	1.48E-06
1.0E+04	2.32E-08*	1.30E-07	3.13E-07	6.30E-07	1.25E-06	1.46E-06	1.48E-06
2.0E+04	3.06E-08*	1.43E-07	3.26E-07	6.37E-07	1.25E-06	1.46E-06	1.48E-06

Accuracy: * - Possible Error Greater Than 10%
** - Possible Error Greater Than 100%

Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

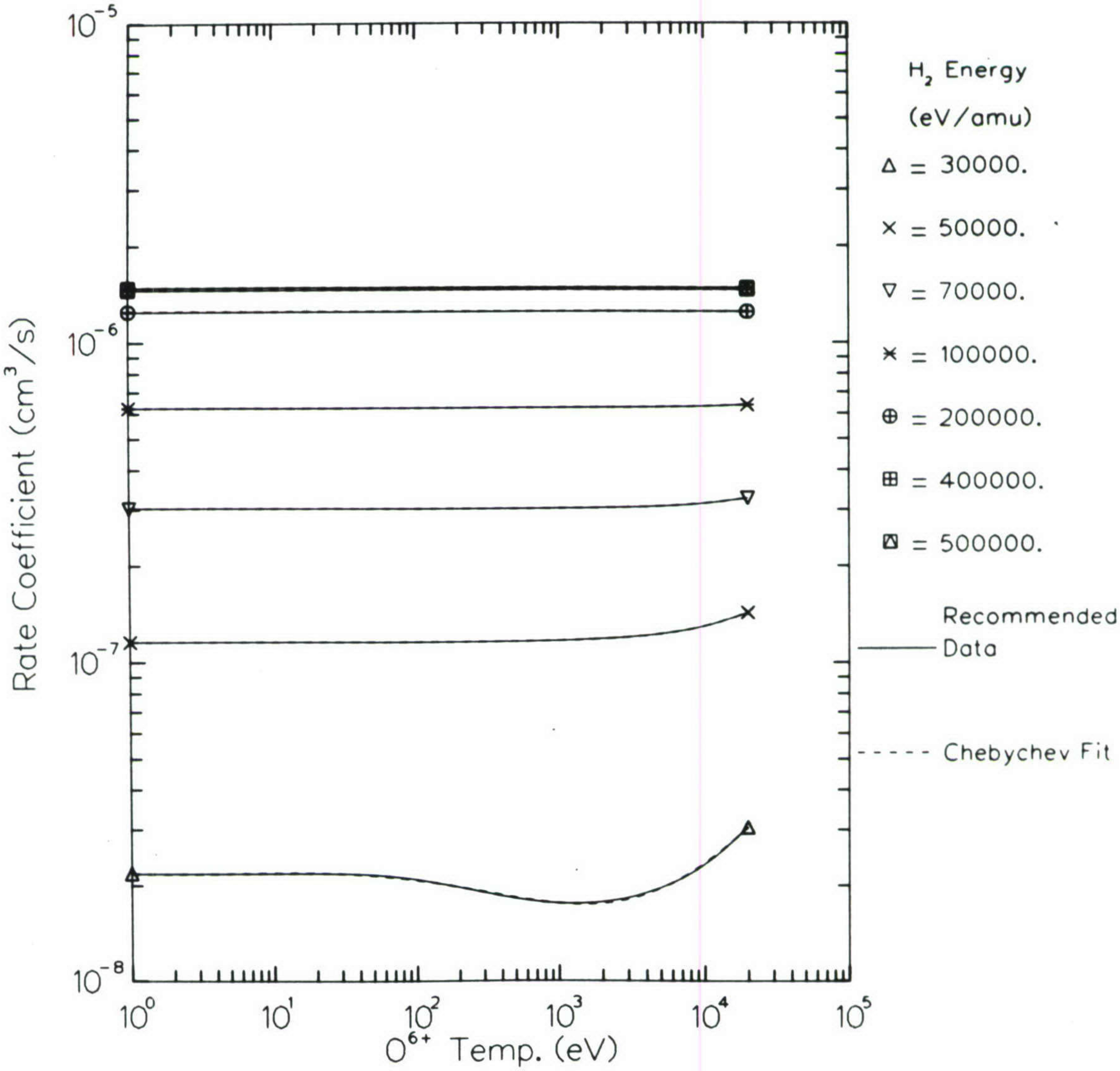
Chebychev Fitting Parameters for Rate Coefficients

H_2 Energy (eV/amu)	C1	C2	C3	C4	C5	C6	C7
30000.	4.372E-08	1.256E-09	2.954E-09	2.930E-09	1.350E-09	6.780E-11	-3.353E-11
50000.	2.414E-07	9.131E-09	6.539E-09	3.794E-09	1.856E-09	7.155E-10	2.502E-10
70000.	6.125E-07	7.307E-09	5.638E-09	3.616E-09	1.739E-09	7.435E-10	2.102E-10
100000.	1.254E-06	2.877E-09	4.322E-09	5.711E-10	1.770E-09	-3.923E-10	6.448E-10
200000.	2.496E-06	-7.154E-10	-7.824E-10	-5.088E-10	-1.746E-10	2.224E-11	7.259E-11
400000.	2.917E-06	8.059E-10	2.866E-10	-1.096E-11	-2.711E-11	-2.352E-11	2.331E-11
500000.	2.958E-06	-5.166E-10	-3.752E-10	-1.861E-10	-4.708E-11	2.859E-11	7.851E-11

See appendix for Chebychev fit details.

$H_2 + O^{6+} -> O^{6+} + H_2^+ + e^-$

Beam – Maxwellian



Ionization Cross Sections for

$O^{7+} + H_2 \rightarrow O^{7+} + H_2^+ + e^-$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
2.9E+04	2.37E+08	5.57E-17
4.0E+04	2.78E+08	1.70E-16
7.0E+04	3.68E+08	9.12E-16
1.0E+05	4.39E+08	1.70E-15
2.0E+05	6.21E+08	2.61E-15
4.0E+05	8.78E+08	2.22E-15
7.0E+05	1.16E+09	1.76E-15
1.0E+06	1.39E+09	1.44E-15
2.0E+06	1.96E+09	9.10E-16
4.0E+06	2.77E+09	5.35E-16
7.0E+06	3.65E+09	3.42E-16
1.0E+07	4.36E+09	2.55E-16

References: T.60

Accuracy: 50% for $E < 1.3\times10^5$ eV/amu; 30% for $E \geq 1.3\times10^5$ eV/amu

Notes: (1) There are no experimental data available for this reaction.

(2) The recommended cross section is for the non-dissociative ionization channel, as are the calculated reaction rate coefficients.

(3) The cross section has been constructed on the basis of the semi-empirical scaling [T.60], with normalization to the maximum cross section obtained from the empirical scalings of E_m (the energy at which the cross section maximum occurs) and $\sigma(E_m)$ determined by $O^{q+} + H_2$ (q = 2-5) experimental data, (see sect. 2.1.1 for details).

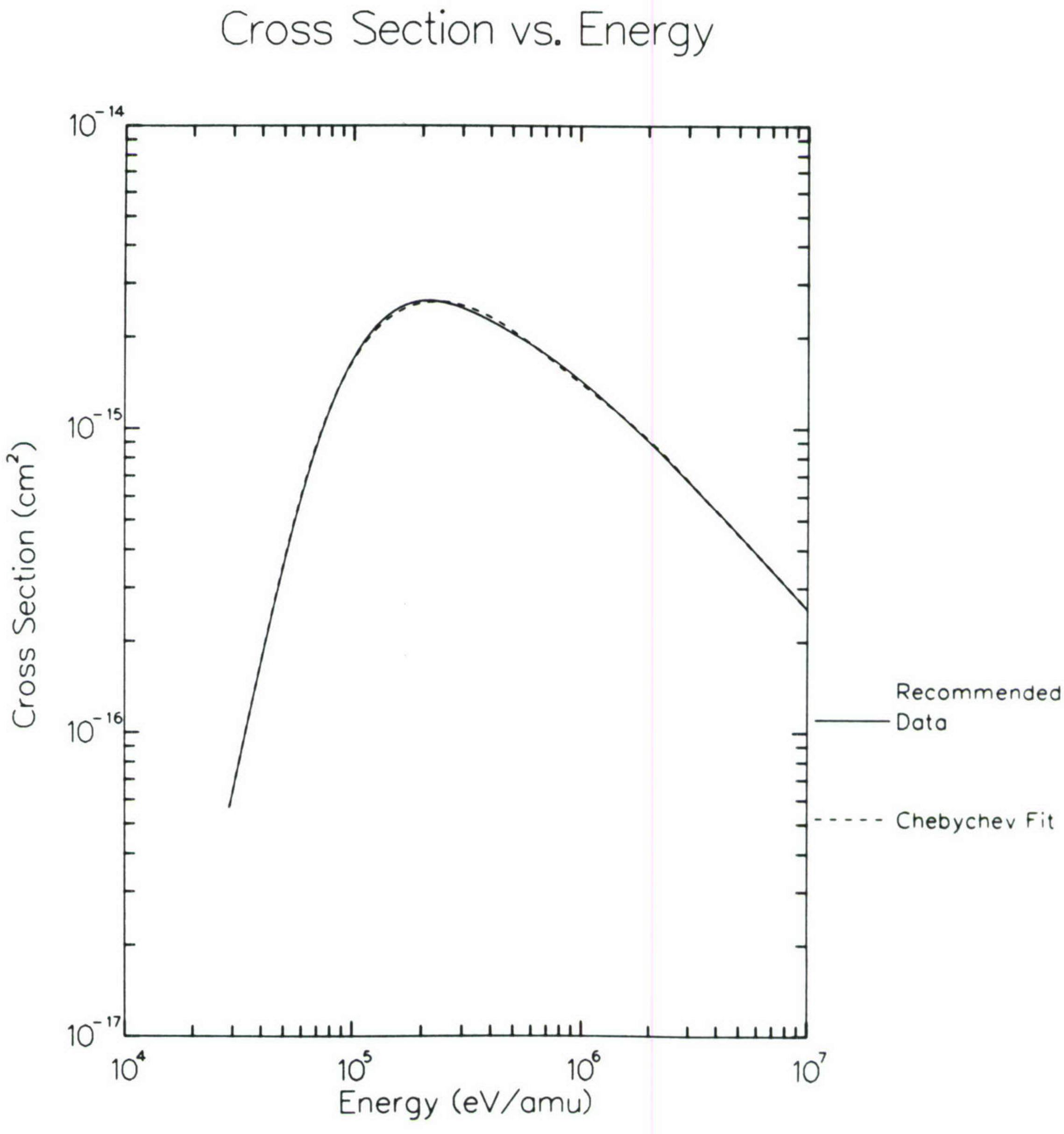
For Chebychev fits of the above cross sections it is necessary to use the following parameters.
E_{min} = 2.9E+04 eV/amu, E_{max} = 1.0E+07 eV/amu

Chebychev Fitting Parameters for Cross Sections

C1	C2	C3	C4	C5	C6	C7	C8	C9
1.883E-15	-1.338E-16	-1.011E-15	4.436E-16	1.985E-16	-2.610E-16	8.100E-17	5.082E-17	-5.427E-17

The fit represents the above cross sections with an rms deviation of 1.9%.
The maximum deviation is 4.4% at 4.0E+05 eV/amu.
See appendix for Chebychev fit details.

$O^{7+} + H_2 \rightarrow O^{7+} + H_2^+ + e^-$



Ionization Rate Coefficients for
$H_2 + O^{7+} \rightarrow O^{7+} + H_2^+ + e^-$

Beam - Maxwellian Rate Coefficients (cm^3/s)

O^{7+} Temp. (eV)	H_2 Energy (eV/amu) 30000.	50000.	70000.	100000.	200000.	400000.	500000.
1.0E+00	1.45E-08	1.05E-07	3.33E-07	7.39E-07	1.62E-06	1.95E-06	2.01E-06
2.0E+00	1.51E-08	1.07E-07	3.35E-07	7.47E-07	1.62E-06	1.95E-06	2.01E-06
4.0E+00	1.52E-08	1.07E-07	3.35E-07	7.47E-07	1.62E-06	1.95E-06	2.01E-06
7.0E+00	1.52E-08	1.07E-07	3.35E-07	7.47E-07	1.62E-06	1.95E-06	2.01E-06
1.0E+01	1.52E-08	1.07E-07	3.35E-07	7.47E-07	1.62E-06	1.95E-06	2.01E-06
2.0E+01	1.52E-08	1.07E-07	3.35E-07	7.47E-07	1.62E-06	1.95E-06	2.01E-06
4.0E+01	1.51E-08	1.07E-07	3.35E-07	7.47E-07	1.62E-06	1.95E-06	2.01E-06
7.0E+01	1.49E-08	1.07E-07	3.35E-07	7.47E-07	1.62E-06	1.95E-06	2.01E-06
1.0E+02	1.46E-08	1.08E-07	3.35E-07	7.47E-07	1.62E-06	1.95E-06	2.01E-06
2.0E+02	1.38E-08*	1.08E-07	3.34E-07	7.47E-07	1.62E-06	1.95E-06	2.01E-06
4.0E+02	1.30E-08*	1.08E-07	3.34E-07	7.48E-07	1.62E-06	1.95E-06	2.01E-06
7.0E+02	1.26E-08*	1.09E-07	3.35E-07	7.48E-07	1.63E-06	1.95E-06	2.01E-06
1.0E+03	1.25E-08*	1.09E-07	3.35E-07	7.49E-07	1.63E-06	1.95E-06	2.01E-06
2.0E+03	1.28E-08*	1.11E-07	3.36E-07	7.50E-07	1.63E-06	1.96E-06	2.01E-06
4.0E+03	1.40E-08*	1.15E-07	3.39E-07	7.52E-07	1.63E-06	1.96E-06	2.01E-06
7.0E+03	1.61E-08*	1.20E-07	3.44E-07	7.56E-07	1.63E-06	1.96E-06	2.01E-06
1.0E+04	1.82E-08*	1.26E-07	3.49E-07	7.59E-07	1.63E-06	1.96E-06	2.01E-06
2.0E+04	2.54E-08*	1.43E-07	3.66E-07	7.68E-07	1.63E-06	1.97E-06	2.01E-06

Accuracy: * - Possible Error Greater Than 10%
** - Possible Error Greater Than 100%

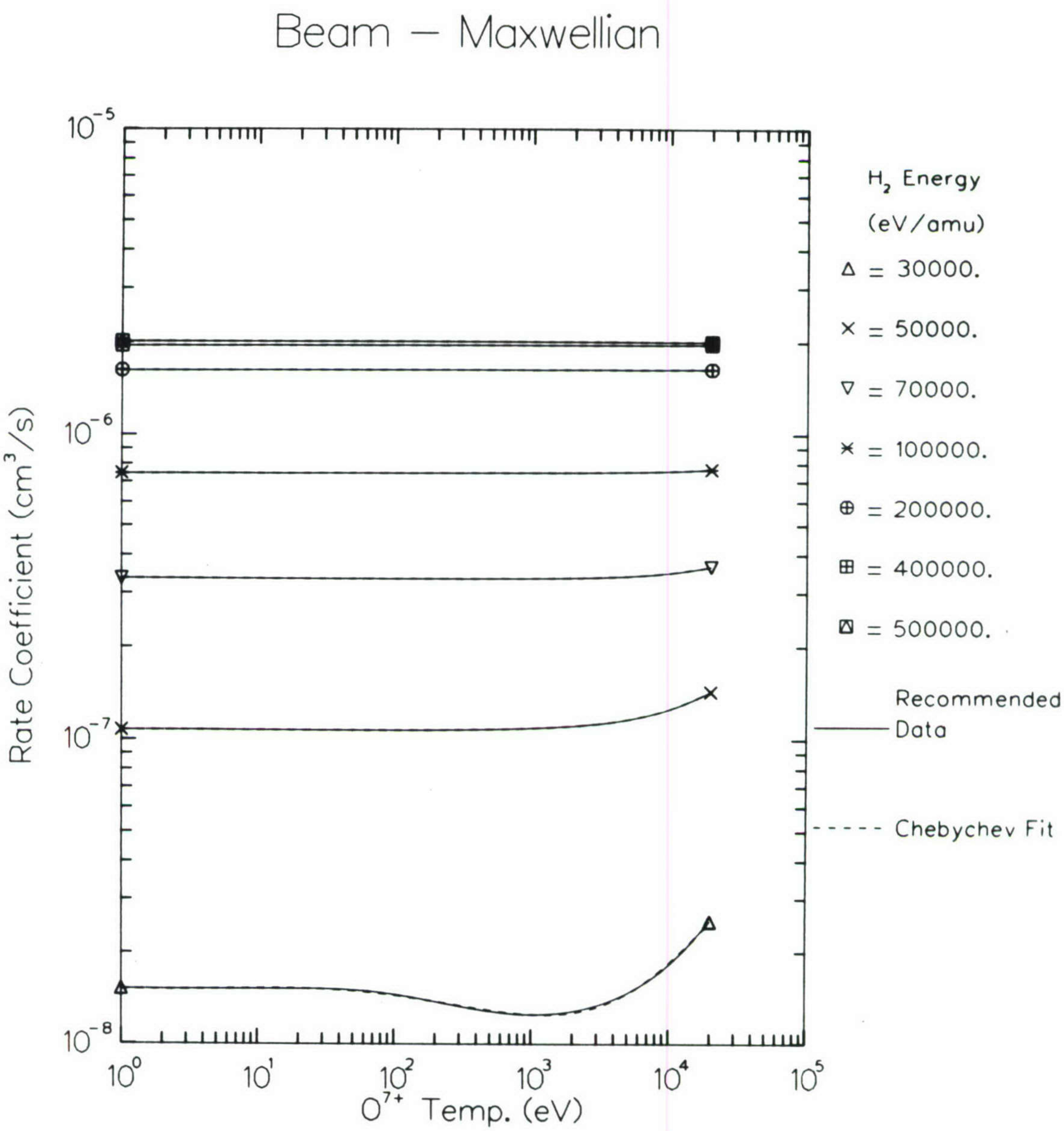
Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

Chebychev Fitting Parameters for Rate Coefficients

H_2 Energy (eV/amu)	C1	C2	C3	C4	C5	C6	C7
30000.	3.181E-08	2.377E-09	2.877E-09	2.696E-09	1.127E-09	2.479E-10	-1.920E-11
50000.	2.276E-07	1.249E-08	8.054E-09	5.449E-09	2.078E-09	1.240E-09	1.119E-10
70000.	6.798E-07	1.007E-08	7.372E-09	5.245E-09	2.188E-09	1.162E-09	1.734E-10
100000.	1.501E-06	9.112E-09	3.671E-09	3.972E-09	2.648E-10	1.282E-09	-4.231E-10
200000.	3.250E-06	5.569E-09	2.032E-09	2.901E-10	-4.815E-11	3.115E-11	8.294E-11
400000.	3.909E-06	6.718E-09	3.087E-09	8.783E-10	1.642E-10	-8.955E-12	2.654E-11
500000.	4.017E-06	-5.295E-10	-3.861E-10	-1.784E-10	-2.594E-11	5.586E-11	1.144E-10

See appendix for Chebychev fit details.

$$H_2 + O^{7+} \rightarrow O^{7+} + H_2^+ + e^-$$



Ionization Cross Sections for
$O^{8+} + H_2 \rightarrow O^{8+} + H_2^+ + e^-$

Energy (eV/amu)	Velocity (cm/s)	Cross Section (cm^2)
2.8E+04	2.32E+08	4.03E-17
4.0E+04	2.78E+08	1.32E-16
7.0E+04	3.68E+08	8.04E-16
1.0E+05	4.39E+08	1.66E-15
2.0E+05	6.21E+08	3.00E-15
4.0E+05	8.78E+08	2.73E-15
7.0E+05	1.16E+09	2.19E-15
1.0E+06	1.39E+09	1.80E-15
2.0E+06	1.96E+09	1.15E-15
4.0E+06	2.77E+09	6.80E-16
7.0E+06	3.65E+09	4.30E-16
1.0E+07	4.36E+09	3.25E-16

References: T.60

Accuracy: 50% for $E < 1.3 \times 10^5$ eV/amu; 30% for $E \geq 1.3 \times 10^5$ eV/amu

Notes: (1) There are no experimental data available for this reaction.
(2) The recommended cross section is for the non-dissociative ionization channel, as are the calculated reaction rate coefficients.
(3) The cross section has been constructed on the basis of the semi-empirical scaling [T.60], with normalization to the maximum cross section obtained from the empirical scalings of E_m (the energy at which the cross section maximum occurs) and $\sigma(E_m)$ determined by $O^{q+} + H_2$ (q = 2-5) experimental data, (see sect. 2.1.1 for details).

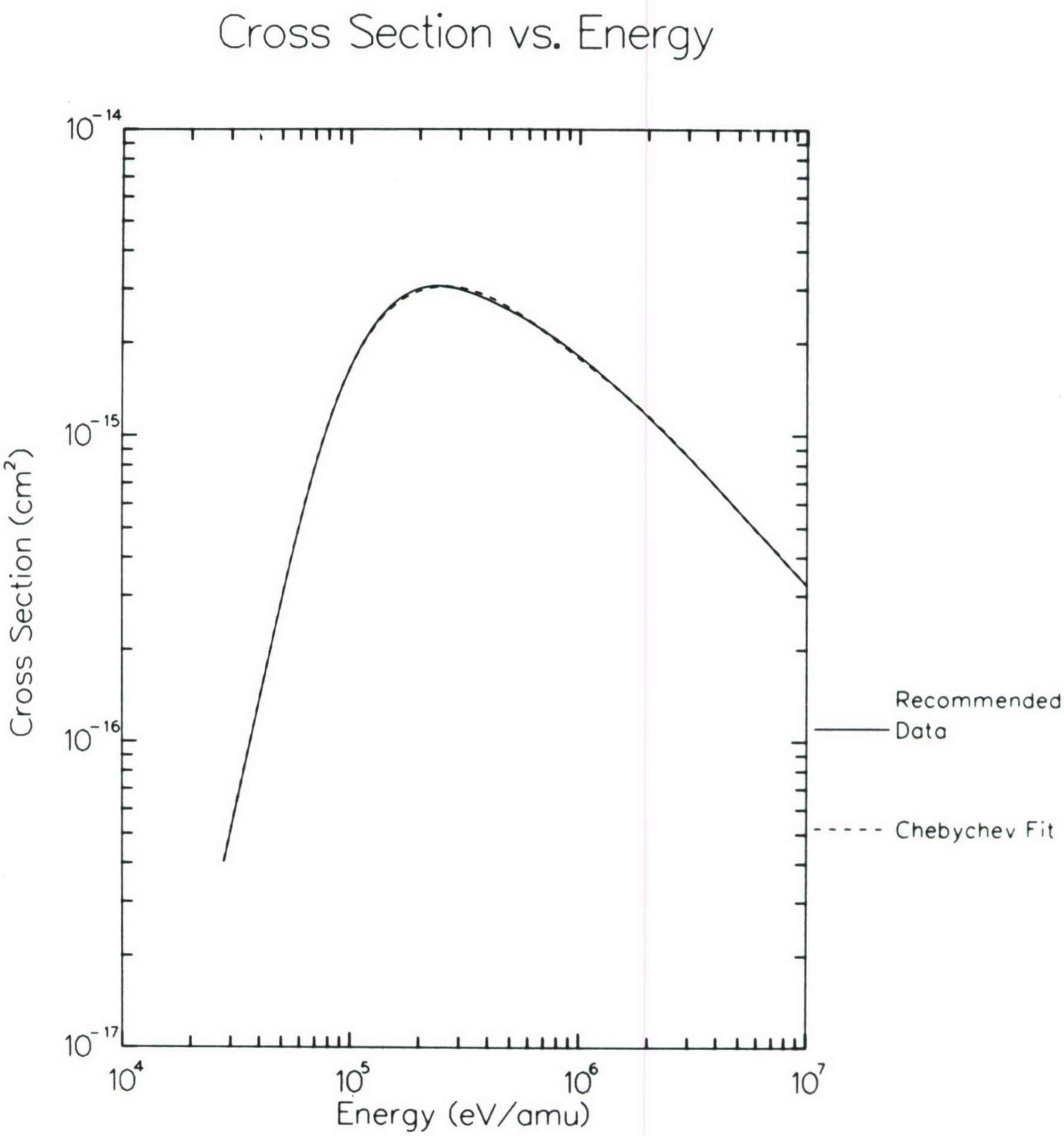
For Chebychev fits of the above cross sections it is necessary to use the following parameters.
E_{min} = 2.8E+04 eV/amu, E_{max} = 1.0E+07 eV/amu

Chebychev Fitting Parameters for Cross Sections

C1	C2	C3	C4	C5	C6	C7	C8	C9
2.159E-15	-4.483E-17	-1.214E-15	4.037E-16	3.423E-16	-3.155E-16	4.592E-17	9.887E-17	-7.095E-17

The fit represents the above cross sections with an rms deviation of 1.4%.
The maximum deviation is 3.4% at 4.0E+05 eV/amu.
See appendix for Chebychev fit details.

$O^{8+} + H_2 \rightarrow O^{8+} + H_2^{+} + e^{-}$



Ionization Rate Coefficients for
$H_2 + O^{8+} \rightarrow O^{8+} + H_2^+ + e^-$

Beam - Maxwellian Rate Coefficients (cm^3/s)

O^{8+} Temp. (eV)	H_2 Energy (eV/amu) 30000.	50000.	70000.	100000.	200000.	400000.	500000.
1.0E+00	1.25E-08	8.50E-08	3.20E-07	7.29E-07	1.86E-06	2.40E-06	2.49E-06
2.0E+00	1.22E-08	8.50E-08	2.97E-07	7.29E-07	1.86E-06	2.40E-06	2.49E-06
4.0E+00	1.22E-08	8.50E-08	2.95E-07	7.29E-07	1.86E-06	2.40E-06	2.49E-06
7.0E+00	1.22E-08	8.50E-08	2.95E-07	7.29E-07	1.86E-06	2.40E-06	2.49E-06
1.0E+01	1.22E-08	8.50E-08	2.95E-07	7.29E-07	1.86E-06	2.40E-06	2.49E-06
2.0E+01	1.22E-08	8.50E-08	2.95E-07	7.29E-07	1.86E-06	2.40E-06	2.49E-06
4.0E+01	1.22E-08	8.50E-08	2.95E-07	7.29E-07	1.86E-06	2.40E-06	2.49E-06
7.0E+01	1.23E-08	8.51E-08	2.95E-07	7.29E-07	1.86E-06	2.40E-06	2.49E-06
1.0E+02	1.23E-08	8.51E-08	2.95E-07	7.29E-07	1.87E-06	2.40E-06	2.49E-06
2.0E+02	1.22E-08	8.53E-08	2.95E-07	7.30E-07	1.87E-06	2.40E-06	2.49E-06
4.0E+02	1.20E-08	8.56E-08	2.95E-07	7.30E-07	1.87E-06	2.40E-06	2.49E-06
7.0E+02	1.17E-08	8.61E-08	2.95E-07	7.31E-07	1.87E-06	2.40E-06	2.49E-06
1.0E+03	1.15E-08*	8.66E-08	2.95E-07	7.31E-07	1.87E-06	2.40E-06	2.49E-06
2.0E+03	1.14E-08*	8.83E-08	2.96E-07	7.33E-07	1.87E-06	2.41E-06	2.49E-06
4.0E+03	1.20E-08*	9.17E-08	3.00E-07	7.36E-07	1.87E-06	2.41E-06	2.49E-06
7.0E+03	1.34E-08*	9.70E-08	3.06E-07	7.41E-07	1.87E-06	2.41E-06	2.49E-06
1.0E+04	1.49E-08*	1.02E-07	3.11E-07	7.45E-07	1.87E-06	2.41E-06	2.49E-06
2.0E+04	2.05E-08*	1.20E-07	3.31E-07	7.59E-07	1.88E-06	2.42E-06	2.49E-06

Accuracy: * - Possible Error Greater Than 10%
** - Possible Error Greater Than 100%

Notes: For Chebychev fits of the above rate coefficients it is necessary to use the following parameters.
E_{min} = 1.0E+00 eV, E_{max} = 2.0E+04 eV

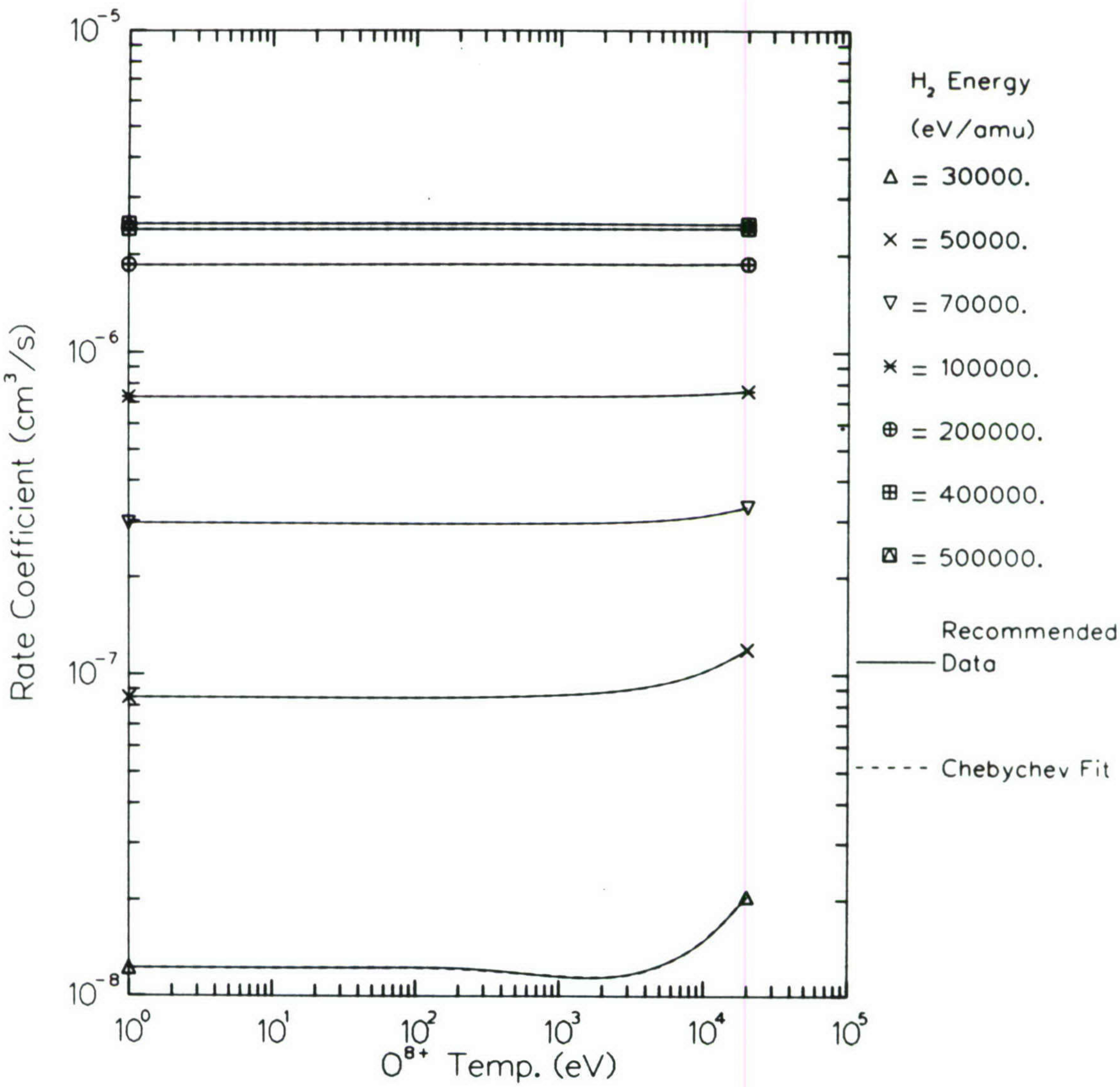
Chebychev Fitting Parameters for Rate Coefficients

H_2 Energy (eV/amu)	C1	C2	C3	C4	C5	C6	C7
30000.	2.659E-08	2.026E-09	2.045E-09	1.595E-09	1.061E-09	3.933E-10	8.417E-11
50000.	1.826E-07	1.141E-08	8.191E-09	4.856E-09	2.394E-09	9.782E-10	3.306E-10
70000.	6.074E-07	5.667E-09	1.356E-08	1.521E-09	6.094E-09	-1.302E-09	2.115E-09
100000.	1.470E-06	1.033E-08	7.108E-09	4.031E-09	1.907E-09	7.565E-10	2.525E-10
200000.	3.735E-06	5.878E-09	2.223E-09	4.104E-10	3.652E-11	9.129E-11	1.213E-10
400000.	4.807E-06	8.763E-09	3.980E-09	1.094E-09	1.793E-10	-2.910E-11	2.586E-11
500000.	4.985E-06	-8.663E-10	-6.287E-10	-3.093E-10	-7.497E-11	5.209E-11	1.363E-10

See appendix for Chebychev fit details.

$$H_2 + O^{8+} \rightarrow O^{8+} + H_2^+ + e^-$$

Beam – Maxwellian



3. Excitation of H, He, and H_2 in Collisions with C^{q+} and O^{q+} Ions

3.1 General Remarks 3-1

3. EXCITATION OF H, He, AND H_2 IN COLLISIONS WITH C^{q+} AND O^{q+} IONS

3.1 General Remarks

Very little investigation has been made of electronic excitation of H, He, and H_2 by C^{q+} and O^{q+} ion impact. Experimental cross section data for excitation in these collision systems do not exist at all, while the theoretical calculations are restricted to the C^{6+} + H system [G.19] [G.27]. In Ref. [G.19], an approximate solution of two-state coupled equation for s-p transition has been obtained by using the dipole approximation to the ion-atom interaction. The general results of this model (DACC) are applicable to A^{q+} + H systems in the high-energy region where A^{q+} can be considered as structureless charged particle, but exclusion of the charge exchange and ionization channels from the treatment, as well as couplings to other excited states, severely restricts the validity of the two-state DACC model. Nevertheless, a factor-of-two accuracy for the 1s→np excitation cross section in the region of its maximum and above (towards the high energy) may be expected from the DACC model for H and He target atoms (the latter being treated in the independent electron model).

In Ref. [G.27], the unitarized distorted wave approximation (UDWA) has been applied to excitation of hydrogen atoms by a few fully stripped ions, including C^{6+}. The UDWA model includes the effects of other inelastic channels (excitation,

charge exchange and ionization) on the particular 1s→np transition through a normalization procedure. Since dynamical channel coupling is not included in the UDWA model, the computed excitation cross section may be uncertain to within a factor of two in the energy region near the cross-section maximum and below. In the high-energy region the UDWA results tend to those predicted by the first Born approximation. For the electronic excitation of H_2 by C^{q+} and O^{q+} ions no theoretical calculations have been performed so far. In view of the factor-of-two (or so) uncertainty of the cross section calculations for C^6 + H excitation collisions, we do not present any recommended data in this section.

3. Excitation of H, He, and H_2 in Collisions with C^{q+} and O^{q+} Ions

3.1 General Remarks 3-1

4. IONIZATION OF C^{q+} AND O^{q+} BY ELECTRON IMPACT

4.1 General Remarks

In this chapter, recommended cross sections and rate coefficients are presented for the electron-impact single-ionization process:

$$e + X^{q+} \rightarrow e + X^{(q+1)+} + e \qquad X = C, O; \; 1 \leq q < Z \qquad (4.1)$$

Both theoretical and experimental data are available for this reaction for each of the ionization stages of C and O. Such collisions have been considered in the compilation of recommended data by Bell and coworkers [G.28], which formed the basis for the present analysis. In some cases, our recommended cross sections are identical to those presented in Ref. [G.28], while other systems have been re-analyzed in the light of additional data which have become available.

Double (or multiple) ionization in a single collision is also possible for many of the ionization stages considered here, but no information is available for such processes involving C and O ions and atoms. Multiple ionization is expected in most cases to be dominated by ionization of an inner-shell electron, followed by autoionization. Multiple-ionization cross sections are expected to be typically at least an order of magnitude smaller than those for single ionization for the lower ionization stages of these light ions, and negligible for the higher stages up to He-like. Thus multiple ionization is not considered in this compilation.

4.1.1 Energy dependence and approximate formulae

At asymptotically high collision energies (i.e., more than about 10 times the ionization threshold, I), the ionization cross section is expected to have the energy dependence given by the Bethe-Born approximation [G.29]:

$$\sigma(E) = \frac{A}{E} \ln (BE) \tag{4.2}$$

where A and B are constants. To a good approximation, the ionization cross section increases linearly with increasing energy from zero at threshold [G.30].

The Lotz formula

The following semiempirical formula has been proposed by Lotz [G.31] to describe the energy dependence of ionization cross section over the entire energy range:

$$\sigma(E) = \sum_{j=1}^{3} a_j \, r_j \, \frac{\ln(E/I_j)}{E \, I_j} \left\{1 - b_j \exp[- c_j(E/I_j - 1)]\right\} \tag{4.3}$$

where

E = incident electron energy in eV

I_j = ionization energy of subshell j in eV

r_j = number of electrons in subshell j

$\sigma(E)$ = ionization cross section in cm^2

a_j, b_j, and c_j are constants determined by experiment, theory, or educated guesswork. Values for these have been tabulated for a number of ions by W. Lotz [G.31]. For ions of charge 4 or greater,

it is customary to set $b_j = c_j = 0$ and $a_j = 4.5 \times 10^{-14}$, which gives the usual one-parameter Lotz formula.

The Lotz formula is widely used in plasma physics, and represents direct or "knock-out" ionization only. It does not account for the process of excitation of an inner-shell electron, followed by autoionization, which makes a non-negligible contribution to the total ionization cross section for a few of the ions considered here (e.g., Li-like ions). This contribution begins at the threshold for the particular inner-shell excitation process. The Lotz semiempirical formula has recently been modified by Burgess and Chidichimo [G.32] to account for this indirect ionization mechanism.

Least-squares fits to recommended cross sections

For consistency in providing least-squares fits to the recommended cross sections in this report, we have adopted the functional form used by Bell and coworkers [G.28]:

$$\sigma(E) = \frac{1}{IE}\left[A\ln(E/I) + \sum_{i=1}^{N} B_i(1 - I/E)^i\right] \tag{4.4}$$

where A and B_i are fitting parameters. This functional form is similar to the Lotz formula, and has approximately the correct threshold behavior and the correct asymptotic high-energy behavior. To extrapolate recommended cross section to the higher energies required for the calculation of

Maxwellian rate coefficients, the first term in Eq. (4.4) was used to represent the high-energy behavior. For this purpose, the coefficient A was determined by normalization to the highest-energy portion of the recommended cross-section curve.

4.1.2 Theoretical methods

A number of theoretical methods have been applied to the calculation of cross sections for electron-impact ionization of atoms and ions. These have been recently summarized by Younger [G.29]. The most successful have been based on the Born Approximation, and include the Coulomb-Born, the Distorted-Wave Born-Exchange and the Close-Coupling Coulomb-Born methods. The latter two approximations generally give good accounts of direct ionization cross sections over the entire energy range. Contributions due to indirect inner-shell excitation-autoionization have also been calculated in the same approximations, and added to the direct ionization cross section, except in the Close-Coupling Coulomb-Born method, where they are implicitly included.

4.1.3 Experimental methods

Experimental cross-section data are available for each of the ionization stages of C and O. The methods which have been applied have been summarized recently by Dunn [G.33]. The majority of the cross-section measurements are based on the crossed-beams method, in which an ion or atom beam intersects

a beam of electrons, and the cross section for ionization at a given electron energy is determined from the measured fraction of ions whose charge has increased by one. While such experiments are technically difficult with low signal levels (especially for multiply charged ions), all relevant parameters can be measured, and experimental cross sections have typical absolute uncertainties of 10% or less. Good energy resolution (~1 eV) is also achievable, providing detailed information about ionization mechanisms.

Useful data has also been obtained by the trapped-ion method, in which ions are confined by some combination of electric and/or magnetic fields, and bombarded by a monoenergetic electron beam. Such measurements are not absolute, and have been normalized to crossed-beams measurements. A variation on this technique involves analysis of the time histories of the populations of charge states of trapped ions produced in an electron-beam ion source (EBIS). The charge-state distribution is determined by time-of-flight analysis of the extracted ions. The ionization cross sections are extracted as fitting parameters in a sequential ionization model for the charge-state populations. While such measurements are less accurate than crossed-beams data, they represent the only data available for the higher ionization stages of C and O. For those cases where data using both methods are available, the agreement is generally within 25% or better.

Rate coefficients have also been determined from measurements on fusion-plamas devices by the plasma spectroscopy method. The rate coefficients become adjustable parameters in a set of coupled rate equations describing the time histories of properly chosen spectral lines radiated by the various ionization stages. Rate coefficients determined in this way are less accurate than those calculated from cross sections measured in crossed-beams or trapped-ion experiments, but are useful for purposes of comparison.

Electron-Impact Ionization Cross Sections for
$e^- + C \rightarrow C^+ + 2e^-$

Energy (eV)	Velocity (cm/s)	Cross Section (cm^2)
1.126E+01	2.00E+08	0.00E+00
2.0E+01	2.65E+08	1.05E-16
4.0E+01	3.74E+08	2.13E-16
5.9E+01	4.57E+08	2.27E-16
7.0E+01	4.99E+08	2.26E-16
1.0E+02	5.95E+08	2.11E-16
2.0E+02	8.41E+08	1.63E-16
4.0E+02	1.19E+09	1.11E-16
7.0E+02	1.57E+09	7.79E-17
1.0E+03	1.87E+09	6.01E-17
2.0E+03	2.64E+09	3.68E-17
4.0E+03	3.73E+09	2.09E-17
7.0E+03	4.91E+09	1.30E-17
1.0E+04	5.84E+09	9.64E-18
2.0E+04	8.15E+09	4.77E-18
4.0E+04	1.12E+10	2.55E-18
7.0E+04	1.43E+10	1.54E-18
1.0E+05	1.64E+10	1.11E-18

References: E.73, T.63

Accuracy: 10%

Notes: (1) The recommended cross section is that given in the compilation [G.28]. The curve follows the crossed-beams experimental data [E.73] from the 11.26 eV threshold to 1 keV, and has been extrapolated to higher energies using the procedure described in section 4.1. This high-energy cross section converges to the Born calculations of Ref. [T.63]. (2) The cross section and calculated rate coefficients represent ionization of C atoms in the ground state.

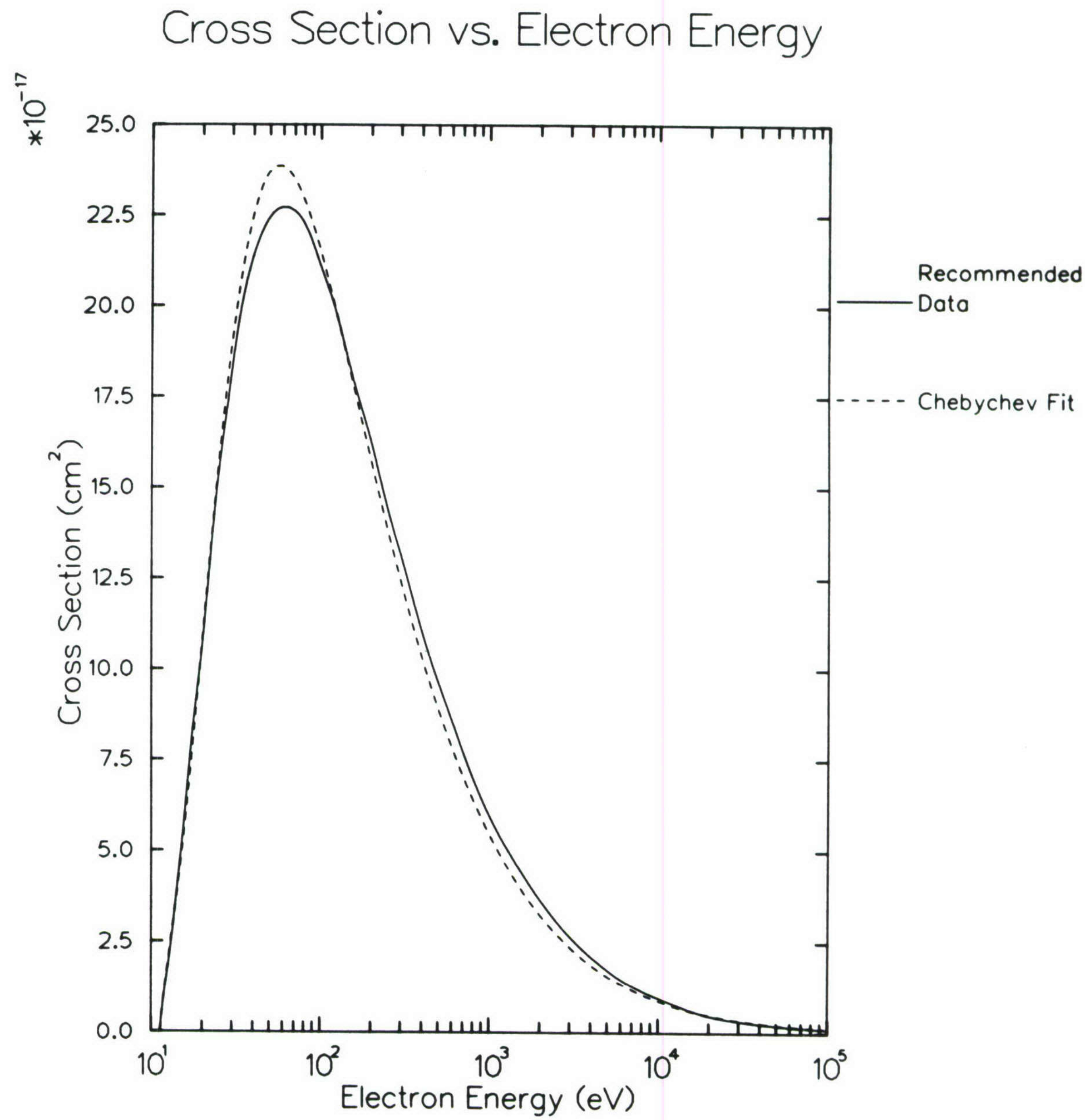
To within an rms deviation of 6.8% the following function can be used to represent the cross section using the parameters below,

Cross Section[cm^2] = $\frac{1}{IE}$ $[A1(\ln(\frac{E}{I})) + B1(1-\frac{I}{E}) + B2(1-\frac{I}{E})^2 + B3(1-\frac{I}{E})^3]$, where $E \geq I$ (I = Ionization Potential = 11.26 eV)

Least Squares Fitting Parameters for Cross Sections

A1	B1	B2	B3
1.6350E-13	-1.3529E-13	-1.1692E-13	1.3919E-13

$e^- + C \rightarrow C^+ + 2e^-$



Electron-Impact Ionization Cross Sections for
$e^- + C^+ \rightarrow C^{2+} + 2e^-$

Energy (eV)	Velocity (cm/s)	Cross Section (cm^2)
2.438E+01	2.94E+08	0.00E+00
4.0E+01	3.80E+08	4.06E-17
7.0E+01	5.04E+08	5.40E-17
8.4E+01	5.44E+08	5.45E-17
1.0E+02	6.04E+08	5.35E-17
2.0E+02	8.50E+08	4.26E-17
4.0E+02	1.19E+09	2.95E-17
7.0E+02	1.57E+09	2.05E-17
1.0E+03	1.87E+09	1.59E-17
2.0E+03	2.64E+09	9.45E-18
4.0E+03	3.73E+09	5.50E-18
7.0E+03	4.91E+09	3.59E-18
1.0E+04	5.84E+09	2.74E-18
2.0E+04	8.15E+09	1.55E-18
4.0E+04	1.12E+10	8.31E-19
7.0E+04	1.43E+10	5.00E-19
1.0E+05	1.64E+10	3.61E-19

References: E.74, E.75, E.76, T.64

Accuracy: 10%

Notes: (1) The recommended cross section is that given in the compilation [G.28], and follows the crossed-beams experimental data [E.74] from the 24.4 eV threshold to 800 eV. Extrapolation to higher energies is based on the procedure described in Section 4.1, and is consistent with Coulomb Born calculations [T.64], and with trapped-ion measurements in the 2-8 keV range [E.75]. The recommended cross section also agrees within the stated uncertainty with lower-energy trapped-ion data [E.76].
(2) Although the measurements show evidence for a small but indeterminate fraction of metastable ^4P ions in the reactant beam (ionization threshold of 19.4 eV), their presence is expected to have a negligible effect on the measured cross section outside the threshold region, and on the deduced reaction rate. The recommended cross section refers to the ground state.

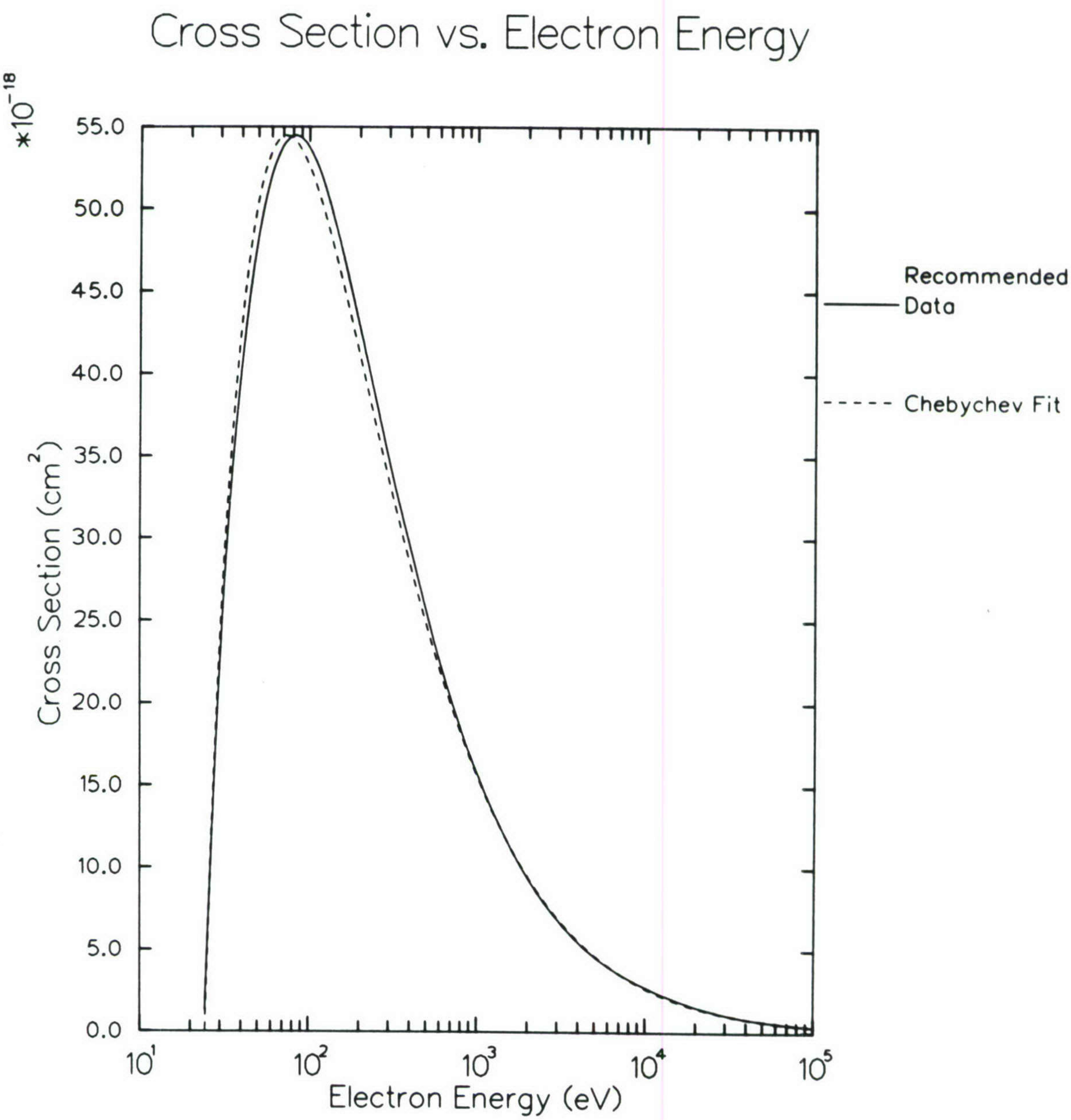
To within an rms deviation of 4.5% the following function can be used to represent the cross section using the parameters below,

Cross Section[cm^2] = $\frac{1}{IE}\left[A1(\ln(\frac{E}{I})) + B1(1-\frac{I}{E}) + B2(1-\frac{I}{E})^2\right]$, where $E \geq I$ (I = Ionization Potential = 24.38 eV)

Least Squares Fitting Parameters for Cross Sections

A1	B1	B2
1.1702E-13	-3.4552E-14	-1.8880E-14

$e^- + C^+ \rightarrow C^{2+} + 2e^-$



Electron-Impact Ionization Cross Sections for
$e^- + C^{2+} \rightarrow C^{3+} + 2e^-$

Energy (eV)	Velocity (cm/s)	Cross Section (cm^2)
4.138E+01	3.83E+08	0.00E+00
7.0E+01	5.05E+08	9.15E-18
1.0E+02	6.07E+08	1.16E-17
1.4E+02	7.04E+08	1.22E-17
2.0E+02	8.50E+08	1.15E-17
4.0E+02	1.21E+09	8.51E-18
7.0E+02	1.59E+09	6.13E-18
1.0E+03	1.87E+09	4.87E-18
2.0E+03	2.64E+09	3.01E-18
4.0E+03	3.73E+09	1.79E-18
7.0E+03	4.91E+09	1.17E-18
1.0E+04	5.84E+09	9.15E-19
2.0E+04	8.15E+09	5.08E-19
4.0E+04	1.12E+10	2.72E-19
7.0E+04	1.43E+10	1.63E-19
1.0E+05	1.64E+10	1.18E-19

References: E.75, E.76, E.77, E.78, T.65, T.66, T.67

Accuracy: 10%

Notes: (1) The recommended cross section follows the independent crossed beams measurements of [E.77, E.78], which are in excellent agreement over their entire range of overlap (threshold to 500 eV).

(2) There is evidence [E.77] that the beams used in these measurements (and for other Be-like ions) contained significant fractions of ions in the metastable $1s^22s2p\ ^3P$ levels, as well as the $1s^22s^2\ ^1S$ ground state (ionization thresholds of 41.4 and 47.9 eV, respectively).

(3) The fractions of metstable and ground-state ions in the beams produced by the ion sources are expected to be approximately typical of the plasmas for which these recommended cross sections and rate coefficients are intended, and therefore the latter have been based on the data for such a "typical" admixture.

(4) The procedure outlined in Section 4.1 has been used to extrapolate the crossed-beam measurements to higher energies, and agrees within the stated uncertainty with both Coulomb-Born [T.65, T.66] and distorted-wave [T.67] calculations.

(5) Trapped-ion measurements in the 2-8 keV energy range are 15-20% higher than the recommended cross section. This is within the stated uncertainties of each.

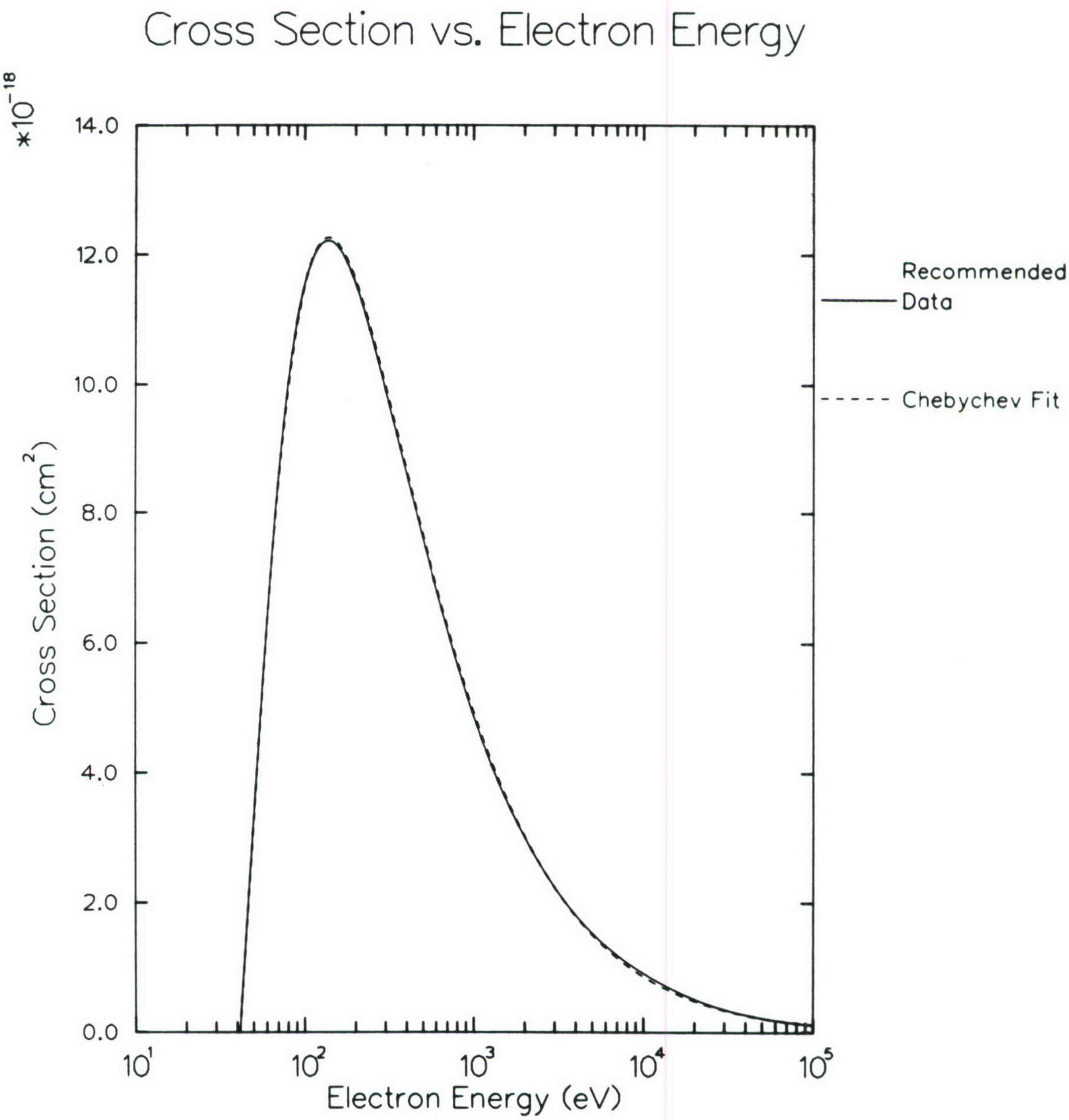
To within an rms deviation of 2.3% the following function can be used to represent the cross section using the parameters below,

Cross Section[cm^2] $= \frac{1}{IE}\left[A1(\ln(\frac{E}{I})) + B1(1-\frac{I}{E}) + B2(1-\frac{I}{E})^2\right]$, where $E \geq I$ (I = Ionization Potential = 41.38 eV)

Least Squares Fitting Parameters for Cross Sections

A1	B1	B2
6.4451E-14	-4.1047E-14	4.3083E-14

$$e^- + C^{2+} \rightarrow C^{3+} + 2e^-$$



Electron-Impact Ionization Cross Sections for
$e^- + C^{3+} \rightarrow C^{4+} + 2e^-$

Energy (eV)	Velocity (cm/s)	Cross Section (cm^2)
6.86E+01	4.78E+08	0.00E+00
7.0E+01	5.00E+08	5.70E-19
1.0E+02	5.93E+08	2.01E-18
1.8E+02	8.03E+08	2.66E-18
2.0E+02	8.37E+08	2.66E-18
2.5E+02	9.31E+08	2.55E-18
2.9E+02	1.01E+09	2.28E-18
3.2E+02	1.06E+09	2.48E-18
3.7E+02	1.14E+09	2.43E-18
4.0E+02	1.19E+09	2.37E-18
7.0E+02	1.58E+09	1.93E-18
1.0E+03	1.87E+09	1.63E-18
2.0E+03	2.64E+09	1.11E-18
4.0E+03	3.73E+09	6.89E-19
7.0E+03	4.91E+09	4.47E-19
1.0E+04	5.84E+09	3.37E-19
2.0E+04	8.15E+09	1.92E-19
4.0E+04	1.12E+10	1.07E-19
7.0E+04	1.43E+10	6.67E-20
1.0E+05	1.64E+10	4.91E-20

References: E.75, E.79, E.80, T.68, T.69, T.70

Accuracy: 15%

Notes: (1) The recommended cross section follows the crossed-beams experimental data [E.79, E.80] over the energy range from the 64.5 eV threshold to 1500 eV.
(2) The measured cross section shows a distinct jump in the 295-310 eV energy range, due to the onset of 1s-nl excitation-autoionization [E.79, T.68]. At energies above 700 eV, the measurements join smoothly to the sum of calculated 1s-nl excitation cross sections [T.68] and either distorted-wave [T.69] or scaled Coulomb-Born [T.70] direct-ionization calculations. The recommended cross section at energies above 1500 eV is that given in the compilation [G.28].
(3) Experimental data based on the trapped-ion method in the 2-8 keV energy range are 20-25% higher than the recommended cross section. This is considered to be within their combined uncertainties.

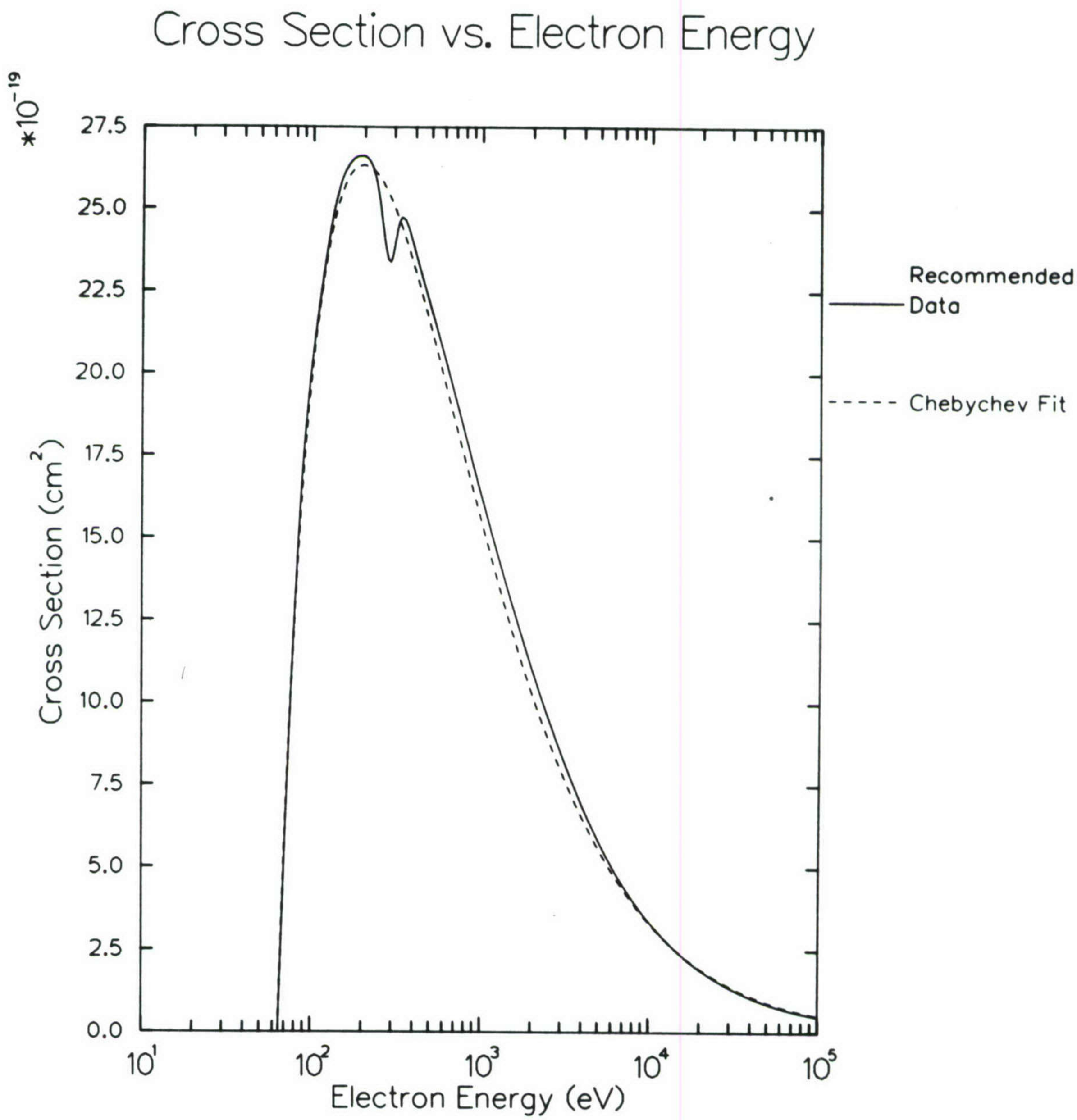
To within an rms deviation of 4.1% the following function can be used to represent the cross section using the parameters below,

Cross Section[cm^2] = $\frac{1}{IE}\left[A1\left(\ln\left(\frac{E}{I}\right)\right) + B1\left(1-\frac{I}{E}\right) + B2\left(1-\frac{I}{E}\right)^2 + B3\left(1-\frac{I}{E}\right)^3\right]$, where $E \geq I$ (I = Ionization Potential = 64.49 eV)

Least Squares Fitting Parameters for Cross Sections

A1	B1	B2	B3
5.1980E-14	-2.1480E-14	-1.4888E-14	-1.1145E-14

$$e^- + C^{3+} \rightarrow C^{4+} + 2e^-$$



Electron-Impact Ionization Cross Sections for
$e^- + C^{4+} \rightarrow C^{5+} + 2e^-$

Energy (eV)	Velocity (cm/s)	Cross Section (cm^2)
3.921E+02	1.19E+09	0.00E+00
4.0E+02	1.19E+09	5.97E-21
7.0E+02	1.59E+09	1.66E-19
1.0E+03	1.87E+09	2.20E-19
1.3E+03	2.13E+09	2.28E-19
2.0E+03	2.64E+09	2.08E-19
4.0E+03	3.73E+09	1.52E-19
7.0E+03	4.91E+09	1.07E-19
1.0E+04	5.84E+09	8.27E-20
2.0E+04	8.15E+09	4.91E-20
4.0E+04	1.12E+10	2.89E-20
7.0E+04	1.43E+10	1.85E-20
1.0E+05	1.64E+10	1.39E-20

References: E.75, E.81, T.71

Accuracy: 15%

Notes: (1) The recommended cross section is based on crossed-beams measurements [E.81] in the 440-1500 eV energy range, and on experimental data obtained by the trapped-ion method [E.75] in the 2-8 keV range.

(2) The curve was extrapolated to higher energies for rate-coefficient calculations using the procedure outlined in section 4.1.

(3) The recommended cross section and rate coefficients are believed to represent ionization from the $1s^2$ ground state.

(4) At energies above 2 keV, the recommended cross section is consistent within the quoted uncertainty with classical calculations using the binary-encounter approximation.

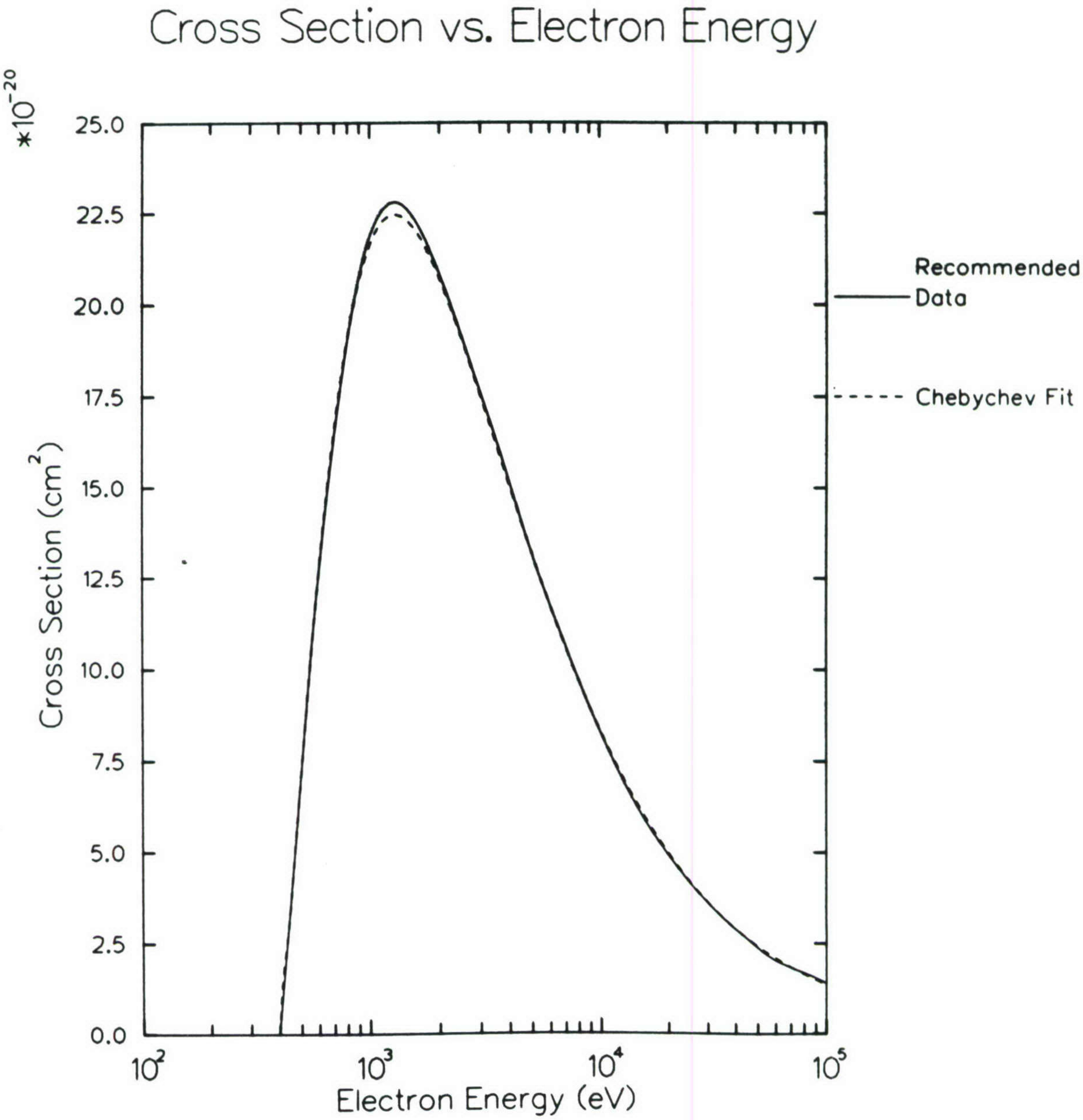
To within an rms deviation of 2.5% the following function can be used to represent the cross section using the parameters below,

Cross Section[cm^2] = $\frac{1}{IE}$ $[A1(\ln(\frac{E}{I})) + B1(1-\frac{I}{E}) + B2(1-\frac{I}{E})^2]$, where $E \geq I$ (I = Ionization Potential = 392.1 eV)

Least Squares Fitting Parameters for Cross Sections

A1	B1	B2
9.0017E-14	-5.8205E-14	9.6802E-14

$e^- + C^{4+} \rightarrow C^{5+} + 2e^-$



Electron-Impact Ionization Cross Sections for
$e^- + C^{5+} \rightarrow C^{6+} + 2e^-$

Energy (eV)	Velocity (cm/s)	Cross Section (cm^2)
4.900E+02	1.32E+09	0.00E+00
5.0E+02	1.33E+09	3.79E-21
7.0E+02	1.57E+09	4.79E-20
1.0E+03	1.87E+09	6.70E-20
1.3E+03	2.13E+09	7.05E-20
2.0E+03	2.64E+09	6.60E-20
4.0E+03	3.73E+09	4.93E-20
5.0E+03	4.16E+09	4.36E-20
6.0E+03	4.55E+09	3.92E-20
7.0E+03	4.91E+09	3.57E-20
8.0E+03	5.24E+09	3.28E-20
9.0E+03	5.55E+09	3.04E-20
1.0E+04	5.84E+09	2.83E-20
2.0E+04	8.15E+09	1.74E-20
3.0E+04	9.84E+09	1.29E-20
4.0E+04	1.12E+10	1.03E-20
5.0E+04	1.24E+10	8.68E-21
6.0E+04	1.34E+10	7.52E-21
7.0E+04	1.43E+10	6.66E-21
8.0E+04	1.51E+10	5.98E-21
9.0E+04	1.58E+10	5.44E-21
1.0E+05	1.64E+10	4.99E-21

References: E.75, T.69

Accuracy: 15%

Notes: (1) There are no crossed-beams measurements for C^{5+}. Experimental data based on the trapped-ion method [E.75] are 30% above distorted-wave calculations [T.69] at an energy of 2 keV, but converge to within 15% at 6-8 keV. As a compromise between the theoretical and experimental data, the recommended cross section represents the distorted-wave calculation, scaled upward by a factor of 1.15.
(2) The recommended cross section is within 1-2% of the Lotz semiempirical estimate (see sect. 4.1).

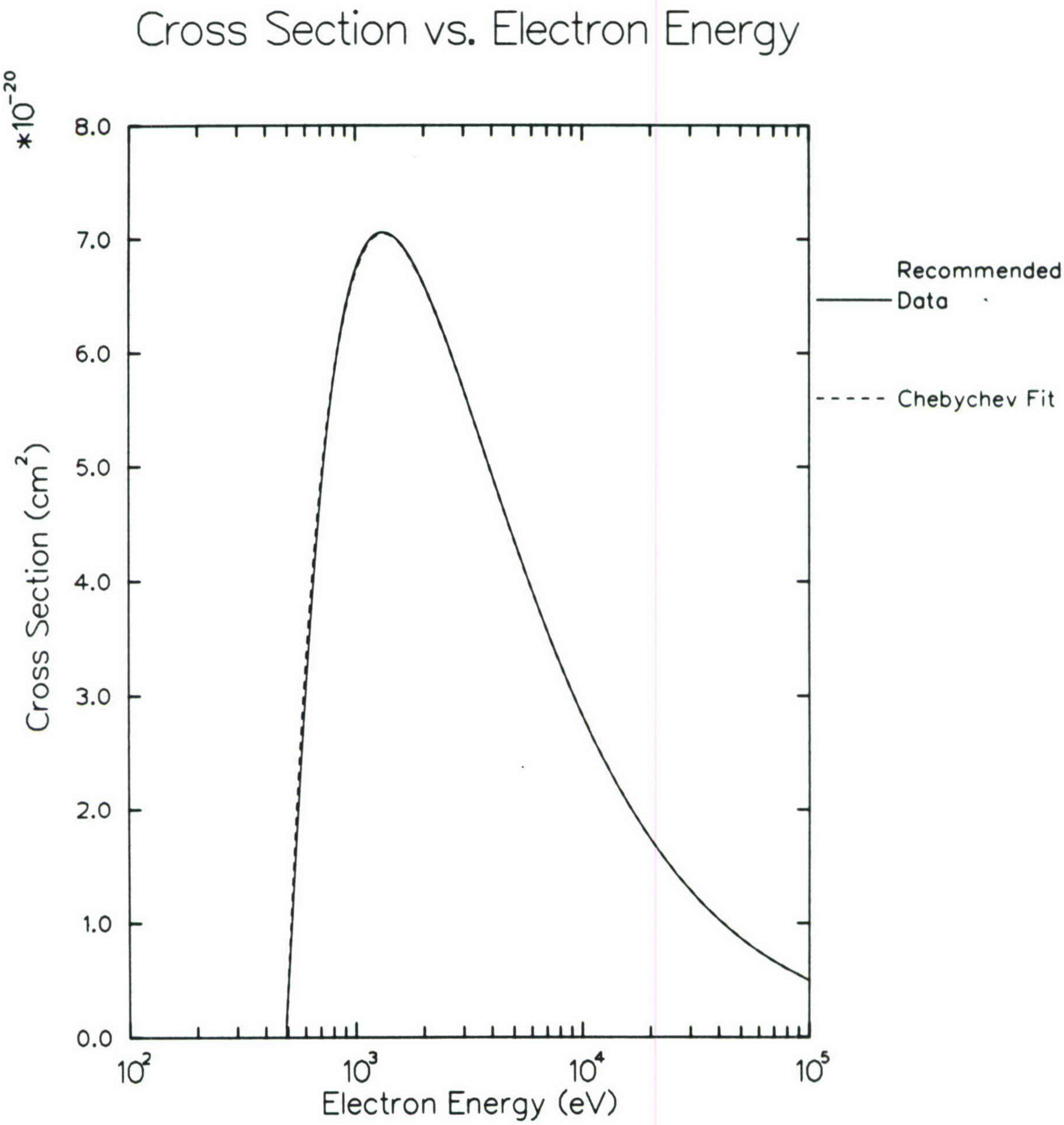
To within an rms deviation of 0.0% the following function can be used to represent the cross section using the parameters below,

Cross Section[cm^2] $= \frac{1}{IE}\left[A1\left(\ln\left(\frac{E}{I}\right)\right)\right]$, where $E \geq I$ (I = Ionization Potential = 490.0 eV)

Least Squares Fitting Parameters for Cross Sections

A1
4.6000E-14

$e^- + C^{5+} \rightarrow C^{6+} + 2e^-$



Electron-Impact Ionization Cross Sections for
$e^- + C^{q+} \rightarrow C^{(q+1)+} + 2e^-$

Maxwellian Rate Coefficients (cm^3/s)

e^- Temp. (eV)	C	C^+	C^{2+}	C^{3+}	C^{4+}	C^{5+}
1.0E+00	3.10E-16	4.22E-25	2.06E-38	0.00E+00**	0.00E+00**	0.00E+00**
2.0E+00	5.44E-12	1.61E-16	2.17E-23	1.34E-24	0.00E+00**	0.00E+00**
4.0E+00	6.99E-10	2.79E-12	6.14E-16	4.36E-17	0.00E+00**	0.00E+00**
7.0E+00	5.82E-09	1.72E-10	8.82E-13	7.44E-14	1.32E-35	0.00E+00**
1.0E+01	1.41E-08	8.84E-10	1.57E-11	1.52E-12	3.09E-28	1.07E-32
2.0E+01	4.20E-08	5.93E-09	4.37E-10	5.66E-11	1.22E-19	7.56E-22
4.0E+01	7.62E-08	1.53E-08	2.27E-09	3.76E-10	2.95E-15	2.60E-16
7.0E+01	9.94E-08	2.29E-08	4.56E-09	8.82E-10	3.30E-13	7.24E-14
1.0E+02	1.10E-07	2.67E-08	5.98E-09	1.26E-09	2.66E-12	7.24E-13
2.0E+02	1.21E-07	3.10E-08	8.00E-09	1.98E-09	3.70E-11	1.13E-11
4.0E+02	1.20E-07	3.16E-08	8.82E-09	2.51E-09	1.51E-10	4.71E-11
7.0E+02	1.13E-07	3.02E-08	8.77E-09	2.75E-09	2.79E-10	8.78E-11
1.0E+03	1.06E-07	2.87E-08	8.50E-09	2.80E-09	3.56E-10	1.13E-10
2.0E+03	9.06E-08	2.52E-08	7.67E-09	2.71E-09	4.57E-10	1.47E-10
4.0E+03	7.39E-08	2.13E-08	6.66E-09	2.42E-09	4.86E-10	1.61E-10
7.0E+03	6.09E-08	1.82E-08	5.77E-09	2.12E-09	4.68E-10	1.58E-10
1.0E+04	5.31E-08	1.62E-08	5.18E-09	1.92E-09	4.43E-10	1.51E-10
2.0E+04	3.89E-08	1.22E-08	3.94E-09	1.49E-09	3.66E-10	1.28E-10

* - Possible Error Greater Than 10%
** - Possible Error Greater Than 100%

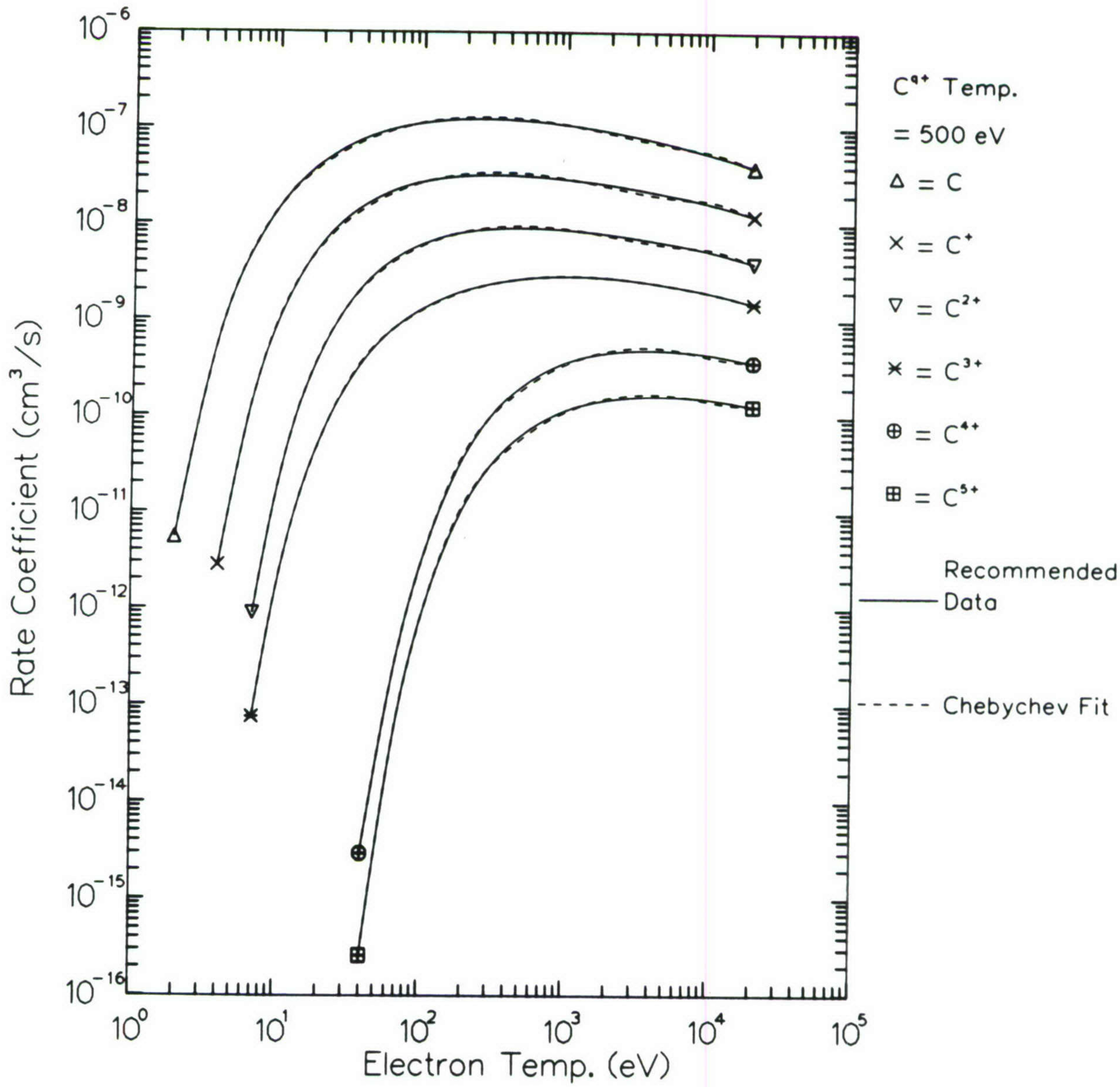
Chebychev Fitting Parameters for Rate Coefficients

	E_{min} (eV)	E_{max} (eV)	C1	C2	C3	C4	C5	C6	C7
C	2.0	2.0E+04	1.090E-07	2.992E-08	-4.748E-08	-9.354E-09	1.802E-08	-1.348E-09	-5.845E-09
C^+	4.0	2.0E+04	3.044E-08	8.641E-09	-1.213E-08	-1.607E-09	4.621E-09	-1.031E-09	-1.710E-09
C^{2+}	7.0	2.0E+04	8.804E-09	2.795E-09	-3.188E-09	-6.010E-10	1.180E-09	-2.497E-10	-4.485E-10
C^{3+}	7.0	2.0E+04	2.741E-09	1.113E-09	-7.997E-10	-4.238E-10	2.343E-10	5.672E-11	-5.945E-11
C^{4+}	40.	2.0E+04	4.783E-10	2.513E-10	-7.327E-11	-9.965E-11	1.234E-11	3.381E-11	7.284E-12
C^{5+}	40.	2.0E+04	1.594E-10	8.604E-11	-2.042E-11	-3.194E-11	2.997E-12	1.052E-11	2.367E-12

See appendix for Chebychev fit details.

$$e^- + C^{q+} \rightarrow C^{(q+1)+} + 2e^-$$

Maxwellian



Electron-Impact Ionization Cross Sections for
$e^- + O \rightarrow O^+ + 2e^-$

Energy (eV)	Velocity (cm/s)	Cross Section (cm^2)
1.362E+01	2.20E+08	0.00E+00
2.0E+01	2.66E+08	3.30E-17
4.0E+01	3.76E+08	9.53E-17
7.0E+01	4.98E+08	1.30E-16
1.0E+02	5.95E+08	1.35E-16
2.0E+02	8.41E+08	1.17E-16
4.0E+02	1.19E+09	8.67E-17
7.0E+02	1.57E+09	6.27E-17
1.0E+03	1.87E+09	4.93E-17
2.0E+03	2.64E+09	3.11E-17
4.0E+03	3.73E+09	1.81E-17
7.0E+03	4.91E+09	1.14E-17
1.0E+04	5.84E+09	8.53E-18
2.0E+04	8.15E+09	4.96E-18
4.0E+04	1.12E+10	2.71E-18
7.0E+04	1.43E+10	1.66E-18
1.0E+05	1.64E+10	1.21E-18

References: E.73, E.82, T.72

Accuracy: 10%

Notes: (1) The recommended cross section is that given in compilation [G.28], and follows the crossed-beams experimental data [E.73] to energies up to 1 keV. Extrapolation to higher energies was based on the procedure described in section 4.1.

(2) The recommended cross section is about 20-25% above plane-wave Born calculations [T.72] at the higher energies (1-10 keV), and 10% lower at the maximum of the cross section near 100 eV.

(3) The cross section and calculated rate coefficients represent ionization of O atoms in the ground state.

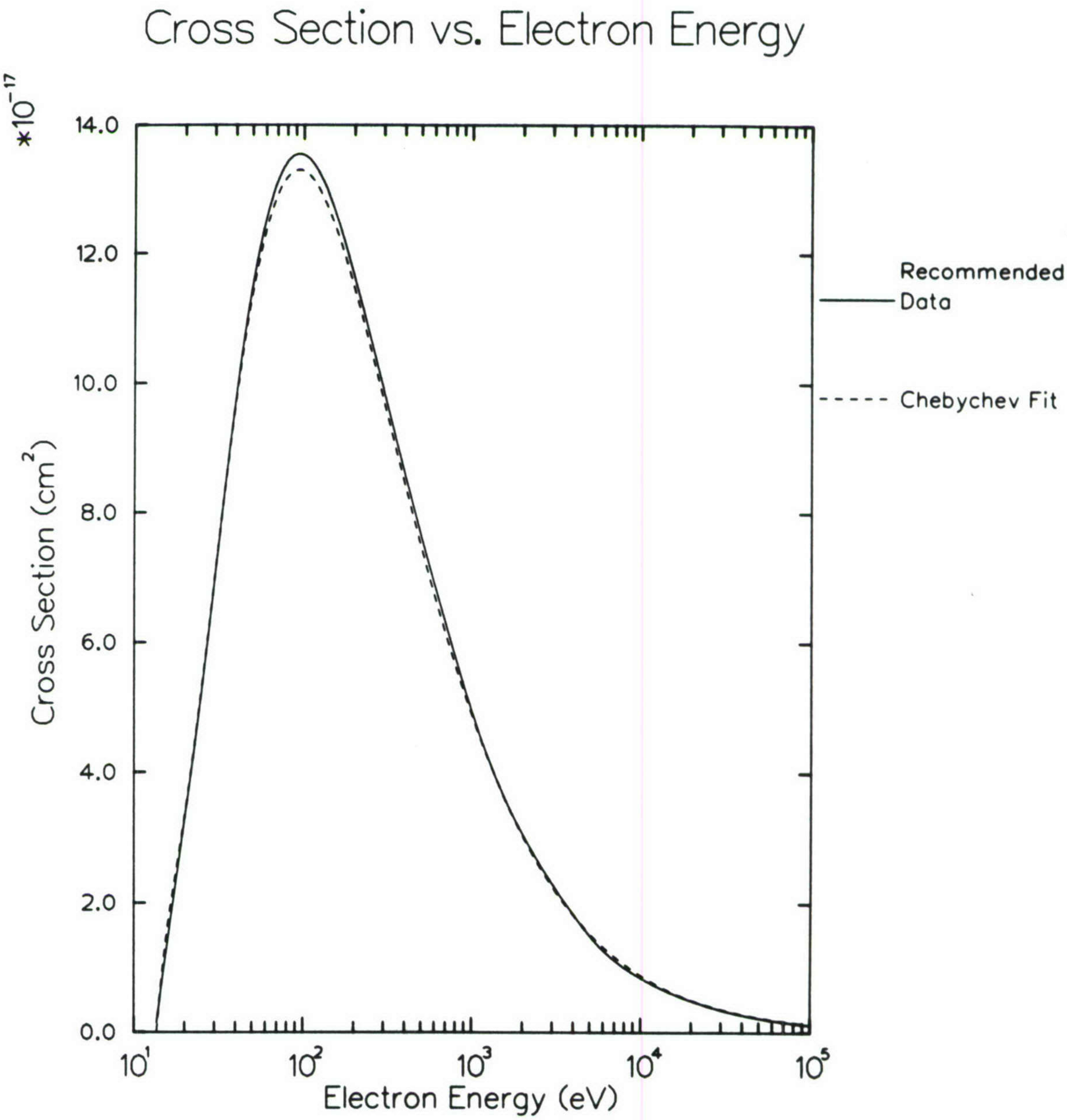
To within an rms deviation of 2.6% the following function can be used to represent the cross section using the parameters below,

Cross Section$[cm^2] = \frac{1}{IE}\left[A1(\ln(\frac{E}{I})) + B1(1-\frac{I}{E}) + B2(1-\frac{I}{E})^2\right]$, where $E \geq I$ (I = Ionization Potential = 13.62 eV)

Least Squares Fitting Parameters for Cross Sections

A1	B1	B2
2.3673E-13	-2.0967E-13	-1.4744E-13

$e^- + O \rightarrow O^+ + 2e^-$



Electron-Impact Ionization Cross Sections for
$e^- + O^+ \rightarrow O^{2+} + 2e^-$

Energy (eV)	Velocity (cm/s)	Cross Section (cm^2)
3.512E+01	3.53E+08	0.00E+00
4.0E+01	3.76E+08	8.46E-18
7.0E+01	4.98E+08	3.21E-17
1.0E+02	5.95E+08	4.16E-17
1.4E+02	6.94E+08	4.42E-17
2.0E+02	8.41E+08	4.23E-17
4.0E+02	1.19E+09	3.24E-17
7.0E+02	1.57E+09	2.36E-17
1.0E+03	1.87E+09	1.87E-17
2.0E+03	2.64E+09	1.13E-17
4.0E+03	3.73E+09	6.39E-18
7.0E+03	4.91E+09	3.88E-18
1.0E+04	5.84E+09	2.76E-18
2.0E+04	8.15E+09	1.68E-18
4.0E+04	1.12E+10	9.34E-19
7.0E+04	1.43E+10	5.76E-19
1.0E+05	1.64E+10	4.22E-19

References: E.76, E.83, E.84, T.64

Accuracy: 10%

Notes: (1) The recommended cross section is that given in the compilation [G.28], and follows the crossed-beams experimental data [E.83] to an energy of 1 keV. Extrapolation to higher energies was based on the procedure described in section 4.1.
(2) The reactant beam used for the crossed-beams measurements [E.83] was estimated to contain about 20% metastable O^+ (^2P or ^2D) ions. Their effect on the measurements is estimated to be less than the quoted uncertainty in the recommended cross section.
(3) At energies above 1 keV, the recommended cross section converges to Coulomb-Born calculations [T.64].

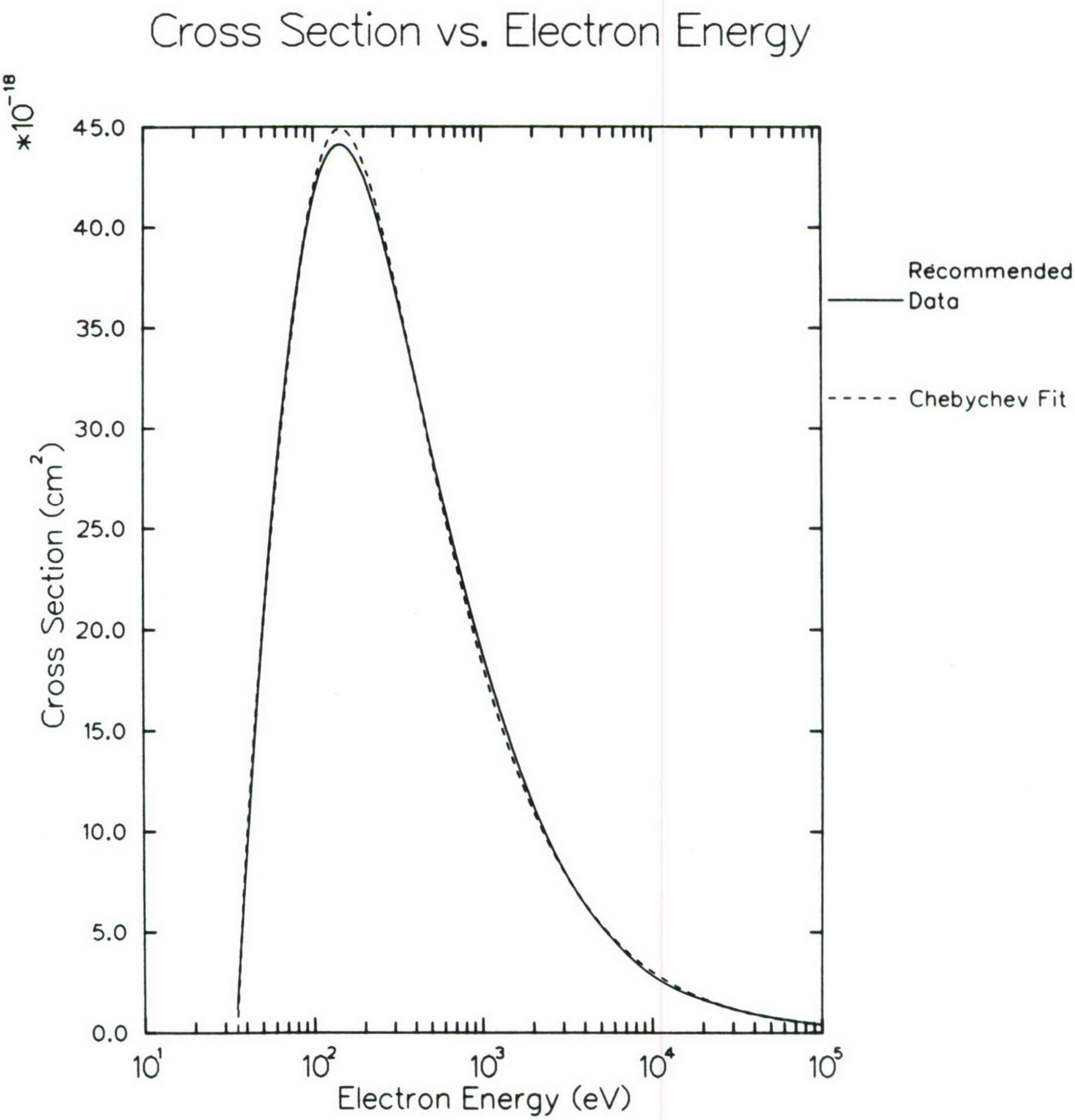
To within an rms deviation of 2.2% the following function can be used to represent the cross section using the parameters below,

Cross Section[cm^2] $= \frac{1}{IE}\,[A1(\ln(\frac{E}{I})) + B1(1-\frac{I}{E}) + B2(1-\frac{I}{E})^2 + B3(1-\frac{I}{E})^3 + B4(1-\frac{I}{E})^4]$, where $E \geq I$ (I = Ionization Potential = 35.12 eV)

Least Squares Fitting Parameters for Cross Sections

A1	B1	B2	B3	B4
1.7420E-13	-7.4347E-14	-1.1018E-13	1.2012E-13	1.4862E-13

$e^- + O^+ \rightarrow O^{2+} + 2e^-$



Electron-Impact Ionization Cross Sections for
$e^- + O^{2+} \rightarrow O^{3+} + 2e^-$

Energy (eV)	Velocity (cm/s)	Cross Section (cm^2)
5.493E+01	4.41E+08	0.00E+00
7.0E+01	4.98E+08	1.01E-17
1.0E+02	5.95E+08	1.53E-17
1.8E+02	8.07E+08	1.90E-17
2.0E+02	8.41E+08	1.90E-17
4.0E+02	1.19E+09	1.58E-17
7.0E+02	1.57E+09	1.18E-17
1.0E+03	1.87E+09	9.65E-18
2.0E+03	2.64E+09	5.93E-18
4.0E+03	3.73E+09	3.42E-18
7.0E+03	4.91E+09	2.08E-18
1.0E+04	5.84E+09	1.50E-18
2.0E+04	8.15E+09	8.91E-19
4.0E+04	1.12E+10	4.98E-19
7.0E+04	1.43E+10	3.09E-19
1.0E+05	1.64E+10	2.27E-19

References: E.75, E.76, E.83, E.88, T.64

Accuracy: 10%

Notes: (1) The recommended cross section below 1 keV is that given in the compilation [G.28]. It follows the crossed-beams experimental data [E.88] from the 54.9 eV threshold to 700 eV, where it joins smoothly to Coulomb- Born calculations [T.64], being 2-5% above the theory.
(2) At energies below 1 keV, the recommended cross section is consistent within the combined uncertanities with other crossed-beams measurements [E.83], and with trapped-ion data [E.76]. Trapped-ion measurements in the 2-8 keV energy range are 15-20% above the Coulomb-Born calculations [T.64]. As a compromise between experiment and theory, the recommended cross section at energies above 1 keV represents these calculations, scaled upward by a factor of 1.1.
(3) There is some evidence for the presence of a small fraction of metastable ^1S and ^1D ions in the reactant beams used in the crossed-beams experiments [E.83, E.88], but their effect on the measured cross section is expected to be negligible beyond the threshold region.

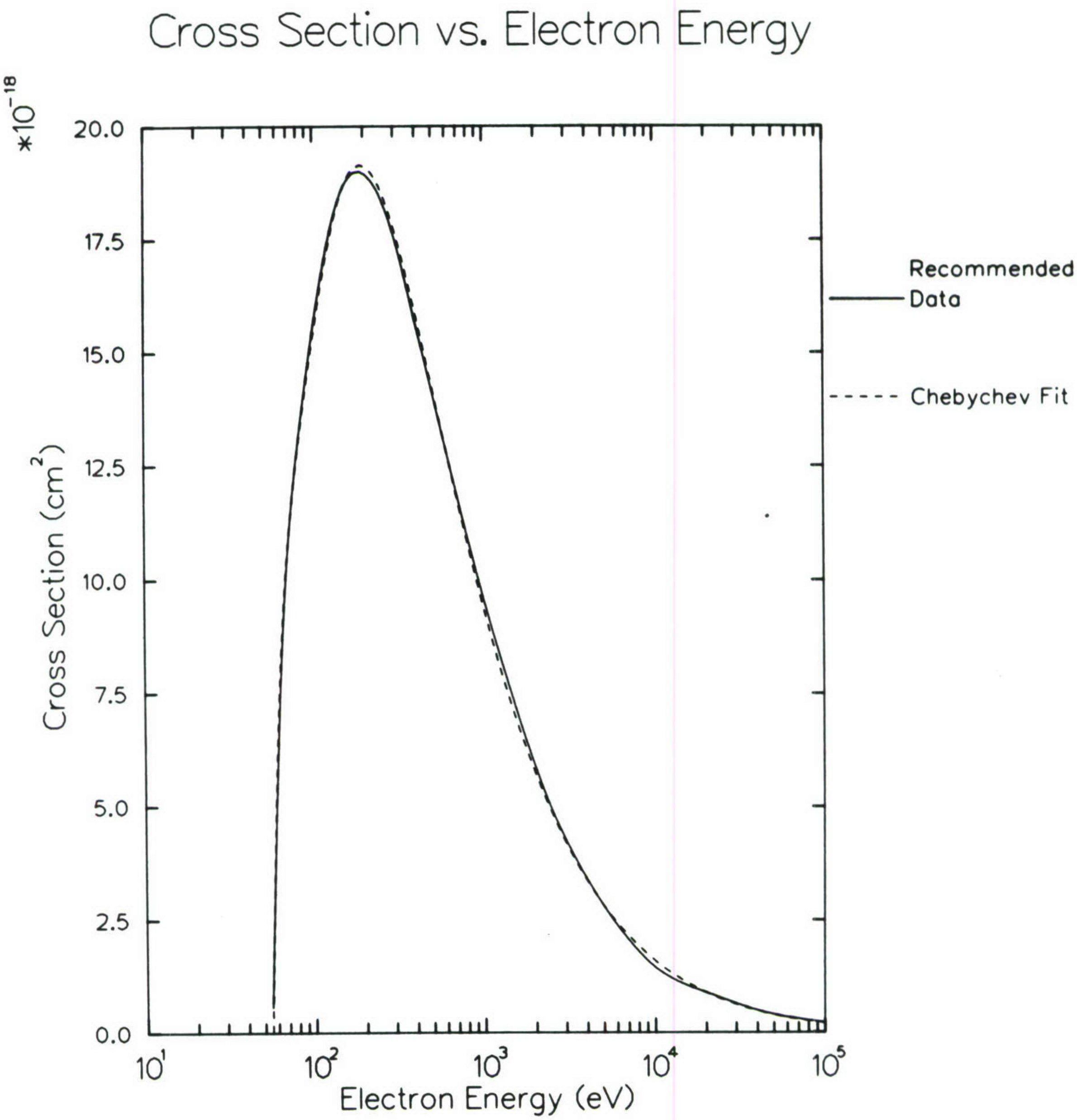
To within an rms deviation of 2.4% the following function can be used to represent the cross section using the parameters below,

Cross Section[cm^2] = $\frac{1}{IE}$ [A1(ln($\frac{E}{I}$)) + B1(1-$\frac{I}{E}$) + B2(1-$\frac{I}{E}$)^2 + B3(1-$\frac{I}{E}$)^3 + B4(1-$\frac{I}{E}$)^4], where $E \geq I$ (I = Ionization Potential = 54.93 eV)

Least Squares Fitting Parameters for Cross Sections

A1	B1	B2	B3	B4
1.4635E-13	1.1907E-13	-6.2116E-13	8.6169E-13	-2.4281E-13

$e^- + O^{2+} \rightarrow O^{3+} + 2e^-$



Electron-Impact Ionization Cross Sections for
$e^- + O^{3+} \rightarrow O^{4+} + 2e^-$

Energy (eV)	Velocity (cm/s)	Cross Section (cm^2)
6.86E+01	4.93E+08	0.00E+00
7.0E+01	4.98E+08	1.44E-19
1.0E+02	5.95E+08	3.84E-18
1.4E+02	7.11E+08	6.25E-18
2.0E+02	8.41E+08	6.67E-18
3.0E+02	1.03E+09	6.91E-18
4.0E+02	1.19E+09	6.48E-18
7.0E+02	1.57E+09	5.19E-18
1.0E+03	1.87E+09	4.22E-18
2.0E+03	2.64E+09	2.71E-18
4.0E+03	3.73E+09	1.69E-18
7.0E+03	4.91E+09	1.12E-18
1.0E+04	5.84E+09	8.65E-19
2.0E+04	8.15E+09	4.80E-19
4.0E+04	1.12E+10	2.69E-19
7.0E+04	1.43E+10	1.67E-19
1.0E+05	1.64E+10	1.23E-19

References: E.75, E.81

Accuracy: 10%

Notes: (1) The recommended cross section is determined by the crossed-beams measurements [E.81] in the energy region from the ionization threshold to 1.5 keV, and by trapped-ion data [E.75] in the 2-8 keV range.

(2) The crossed-beams data [E.81] refer to an O^{3+} beam having an estimated $(1s^2 2s2p^2)\ ^4P$ metastable fraction of 16% (I.P. of 68.6 eV), with the balance in the ground state $(1s^2 2s^2 2p)\ ^2P$ (I.P. of 77.4 eV). Such a state admixture is expected to be roughly typical of the plasma applications for which these recommended data are intended and thus the recommended cross section follows these data.

(3) The recommended cross section is 10-15% higher than Coulomb-Born calculations for ground-state ions [T.73].

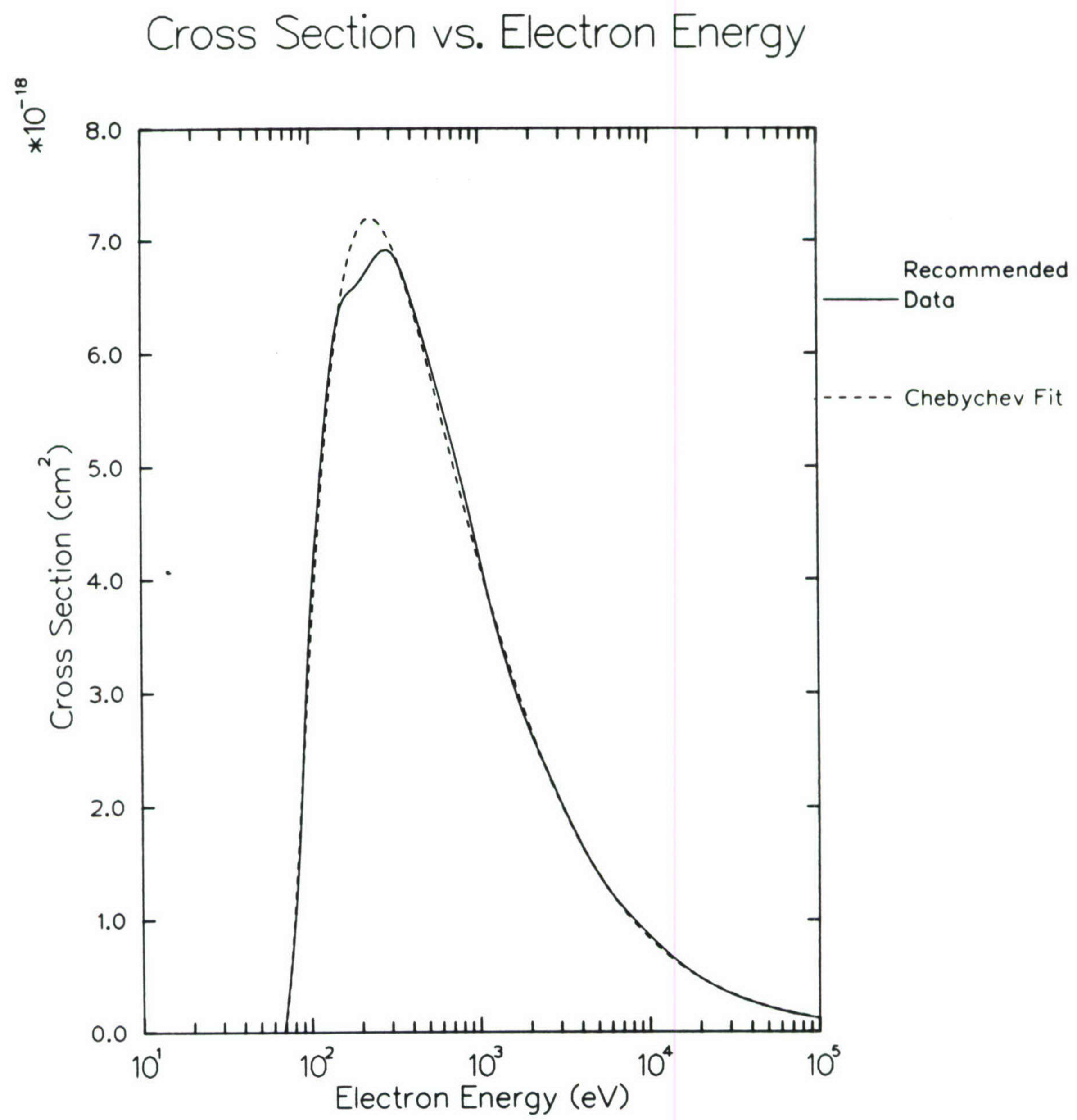
To within an rms deviation of 3.7% the following function can be used to represent the cross section using the parameters below,

Cross Section$[cm^2] = \frac{1}{IE}\,[A1(\ln(\frac{E}{I})) + B1(1-\frac{I}{E}) + B2(1-\frac{I}{E})^2 + B3(1-\frac{I}{E})^3 + B4(1-\frac{I}{E})^4]$, where $E \geq I$ (I = Ionization Potential = 68.6 eV)

Least Squares Fitting Parameters for Cross Sections

A1	B1	B2	B3	B4
1.2658E-13	-1.1441E-13	1.3683E-13	-6.1991E-14	-2.1691E-14

$e^- + O^{3+} \rightarrow O^{4+} + 2e^-$



Electron-Impact Ionization Cross Sections for
$e^- + O^{4+} \rightarrow O^{5+} + 2e^-$

Energy (eV)	Velocity (cm/s)	Cross Section (cm^2)
1.037E+02	6.06E+08	0.00E+00
2.0E+02	8.41E+08	2.57E-18
3.0E+02	1.03E+09	2.92E-18
4.0E+02	1.19E+09	2.84E-18
5.0E+02	1.33E+09	2.67E-18
6.0E+02	1.46E+09	2.66E-18
7.0E+02	1.57E+09	2.52E-18
1.0E+03	1.87E+09	2.00E-18
2.0E+03	2.64E+09	1.27E-18
4.0E+03	3.73E+09	7.82E-19
7.0E+03	4.91E+09	5.17E-19
1.0E+04	5.84E+09	3.98E-19
2.0E+04	8.15E+09	2.25E-19
4.0E+04	1.12E+10	1.27E-19
7.0E+04	1.43E+10	7.95E-20
1.0E+05	1.64E+10	5.87E-20

References: E.75, E.77, T.74, T.75

Accuracy: 10%

Notes: (1) The recommended cross section is based on crossed-beams measurements [E.77] in the region from the 104 eV threshold to 1.5 keV, and on trapped-ion data [E.75] in the 2-8 keV range.

(2) There is evidence [E.77] that the ion beams used for the crossed-beams measurements contained substantial fractions (possibly as high as 90%) in the $1s^22s2p$ metastable levels. This is expected to be typical for Be-like ions, and of the plasma applications for which these recommended data are intended. Thus the recommended cross section refers to such a "typical" admixture.

(3) Distorted-wave direct-ionization calculations [T.74] for the $1s^22s2p$ metastable level only are about 20% below the measurements and the recommended cross section at energies above approximately 200 eV, but agree well at lower energies. The measurements [E.77] show evidence for the onset of 1s-nl excitation-autoionization in the 540 eV energy region, consistent in magnitude with theoretical predictions [T.75].

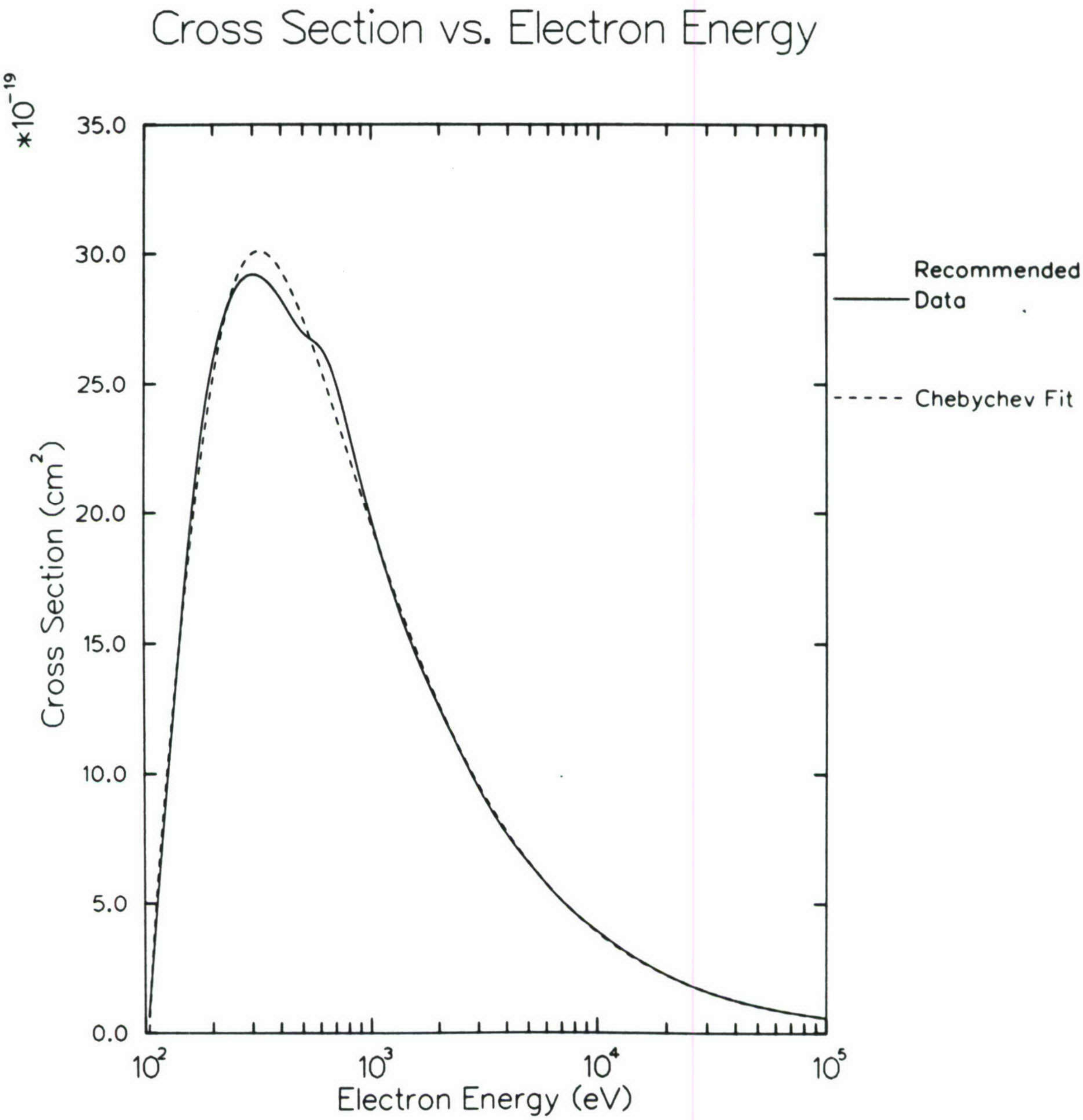
To within an rms deviation of 3.0% the following function can be used to represent the cross section using the parameters below,

Cross Section[cm^2] = $\frac{1}{IE}\left[A1(\ln(\frac{E}{I})) + B1(1-\frac{I}{E}) + B2(1-\frac{I}{E})^2 + B3(1-\frac{I}{E})^3 + B4(1-\frac{I}{E})^4\right]$, where $E \geq I$ (I = Ionization Potential = 103.7 eV)

Least Squares Fitting Parameters for Cross Sections

A1	B1	B2	B3	B4
8.9323E-14	-7.2049E-15	-1.6416E-13	4.4403E-13	-2.7819E-13

$e^- + O^{4+} \rightarrow O^{5+} + 2e^-$



Electron-Impact Ionization Cross Sections for
$e^- + O^{5+} \rightarrow O^{6+} + 2e^-$

Energy (eV)	Velocity (cm/s)	Cross Section (cm^2)
1.381E+02	6.99E+08	0.00E+00
2.0E+02	8.41E+08	4.76E-19
4.0E+02	1.19E+09	7.20E-19
5.5E+02	1.39E+09	7.00E-19
5.7E+02	1.42E+09	7.61E-19
7.0E+02	1.57E+09	7.23E-19
1.0E+03	1.87E+09	6.41E-19
2.0E+03	2.64E+09	4.80E-19
4.0E+03	3.73E+09	3.04E-19
7.0E+03	4.91E+09	2.02E-19
1.0E+04	5.84E+09	1.54E-19
2.0E+04	8.15E+09	8.97E-20
4.0E+04	1.12E+10	5.11E-20
7.0E+04	1.43E+10	3.21E-20
1.0E+05	1.64E+10	2.38E-20

References: E.75, E.79, E.85, E.86, E.87, T.65, T.70

Accuracy: 5% for $E \leq 10^3$ eV; 15% for $E > 10^3$ eV

Notes: (1) The recommended cross section in the region from the 138.1 eV threshold to 2.5 keV is determined by independent crossed-beams measurements [E.79, E.85, E.86, E.87], and is consistent within a few percent with Coulomb-Born [T.65] and scaled Coulomb-Born [T.70] calculations.

(2) The experimental cross section shows a distinct jump of about 10% in the 550-600 eV region, due to 1s-nl excitation-autoionization. This contribution has been included in the theoretical calculations noted above [T.65, T.70].

(3) The highest energy crossed-beams measurements [E.86] near 2.5 keV are consistent with experimental data based on the trapped-ion method [E.75]. The recommended cross section at energies above 2.5 keV represents a compromise between the trapped-ion measurements, and an extrapolation of the theoretical cross sections [T.65, T.70] using the procedure described in section 4.1.

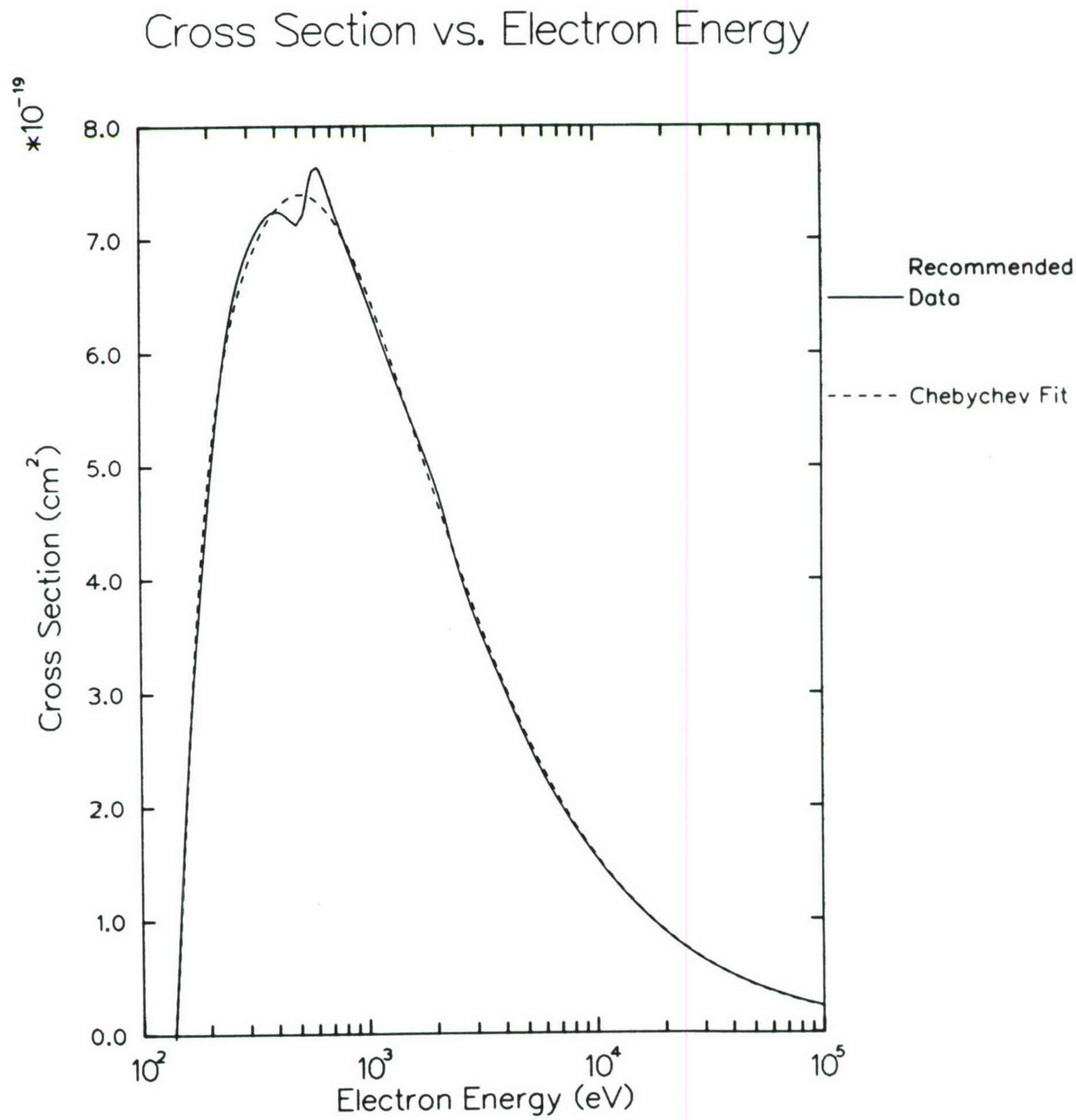
To within an rms deviation of 3.8% the following function can be used to represent the cross section using the parameters below,

Cross Section[cm^2] = $\frac{1}{IE}\left[A1(\ln(\frac{E}{I})) + B1(1-\frac{I}{E}) + B2(1-\frac{I}{E})^2 + B3(1-\frac{I}{E})^3 + B4(1-\frac{I}{E})^4\right]$, where $E \geq I$ (I = Ionization Potential = 138.1 eV)

Least Squares Fitting Parameters for Cross Sections

A1	B1	B2	B3	B4
4.4995E-14	-2.3344E-14	1.1111E-13	-2.9393E-13	2.3062E-13

$e^- + O^{5+} \rightarrow O^{6+} + 2e^-$



Electron-Impact Ionization Cross Sections for
$e^- + O^{6+} \rightarrow O^{7+} + 2e^-$

Energy (eV)	Velocity (cm/s)	Cross Section (cm^2)
7.393E+02	1.62E+09	0.00E+00
1.0E+03	1.87E+09	2.09E-20
2.0E+03	2.64E+09	5.63E-20
2.4E+03	2.89E+09	5.73E-20
3.0E+03	2.89E+09	5.62E-20
4.0E+03	3.73E+09	5.17E-20
5.0E+03	4.16E+09	4.68E-20
6.0E+03	4.55E+09	4.27E-20
7.0E+03	4.91E+09	3.93E-20
8.0E+03	5.24E+09	3.67E-20
9.0E+03	5.55E+09	3.41E-20
1.0E+04	5.84E+09	3.19E-20
2.0E+04	8.15E+09	1.95E-20
3.0E+04	9.84E+09	1.47E-20
4.0E+04	1.12E+10	1.23E-20
5.0E+04	1.24E+10	1.07E-20
6.0E+04	1.34E+10	9.54E-21
7.0E+04	1.43E+10	8.69E-21
8.0E+04	1.51E+10	7.96E-21
9.0E+04	1.58E+10	7.22E-21
1.0E+05	1.64E+10	6.57E-21

References: E.75, T.76

Accuracy: 20% for $0.8 \leq E(\text{keV}) \leq 1.5$; 15% for $E > 1.5$ keV

Notes: (1) The recommended cross section is that given in compilation [G.28], and is based on classical scaling of data for other He-like ions. It agrees within 10% with trapped-ion measurements in the 2-8 keV energy range [E.75], coinciding with them at the cross section maximum near 2.5 keV.

(2) The recommended cross section converges to semiempirical results for He-like ions [T.76] at energies above 5 keV.

(3) The cross section and calculated rate coefficients refer to ground state ions.

To within an rms deviation of 4.5% the following function can be used to represent the cross section using the parameters below,

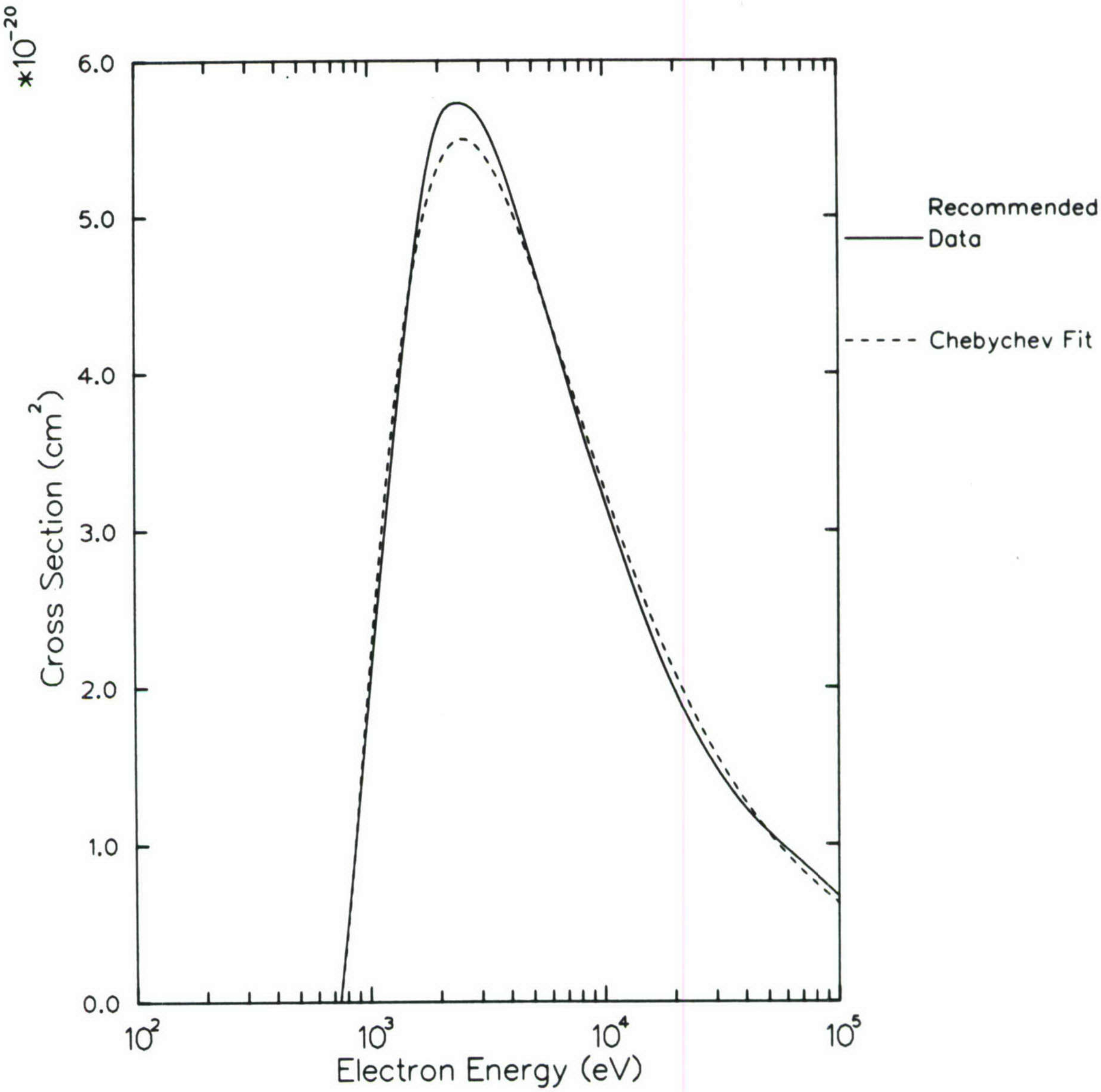
Cross Section[cm^2] = $\frac{1}{IE}\left[A1(\ln(\frac{E}{I})) + B1(1-\frac{I}{E}) + B2(1-\frac{I}{E})^2\right]$, where $E \geq I$ (I = Ionization Potential = 739.3 eV)

Least Squares Fitting Parameters for Cross Sections

A1	B1	B2
9.3515E-14	-6.8707E-14	7.2509E-14

$e^- + O^{6+} \rightarrow O^{7+} + 2e^-$

Cross Section vs. Electron Energy



Electron-Impact Ionization Cross Sections for
$e^- + O^{7+} \rightarrow O^{8+} + 2e^-$

Energy (eV)	Velocity (cm/s)	Cross Section (cm^2)
8.714E+02	1.76E+09	0.00E+00
1.0E+03	1.87E+09	6.69E-21
2.0E+03	2.64E+09	2.02E-20
2.3E+03	2.83E+09	2.06E-20
4.0E+03	3.73E+09	1.85E-20
5.0E+03	4.16E+09	1.70E-20
6.0E+03	4.55E+09	1.56E-20
7.0E+03	4.91E+09	1.45E-20
8.0E+03	5.24E+09	1.35E-20
9.0E+03	5.55E+09	1.26E-20
1.0E+04	5.84E+09	1.19E-20
2.0E+04	8.15E+09	7.61E-21
3.0E+04	9.84E+09	5.73E-21
4.0E+04	1.12E+10	4.65E-21
5.0E+04	1.24E+10	3.94E-21
6.0E+04	1.34E+10	3.43E-21
7.0E+04	1.43E+10	3.05E-21
8.0E+04	1.51E+10	2.75E-21
9.0E+04	1.58E+10	2.54E-21
1.0E+05	1.64E+10	2.31E-21

References: E.75, T.69

Accuracy: 10%

Notes: (1) The recommended cross section is that given in the compilation [G.28], scaled by a factor of 1.06 to better represent the trapped-ion experimental results [E.75] in the 2-8 keV energy range.
(2) The recommended cross section is consistent within the quoted uncertainty with distorted-wave calculations [T.69] for C^{5+}, scaled according to the classical prescription given in section 4.1.

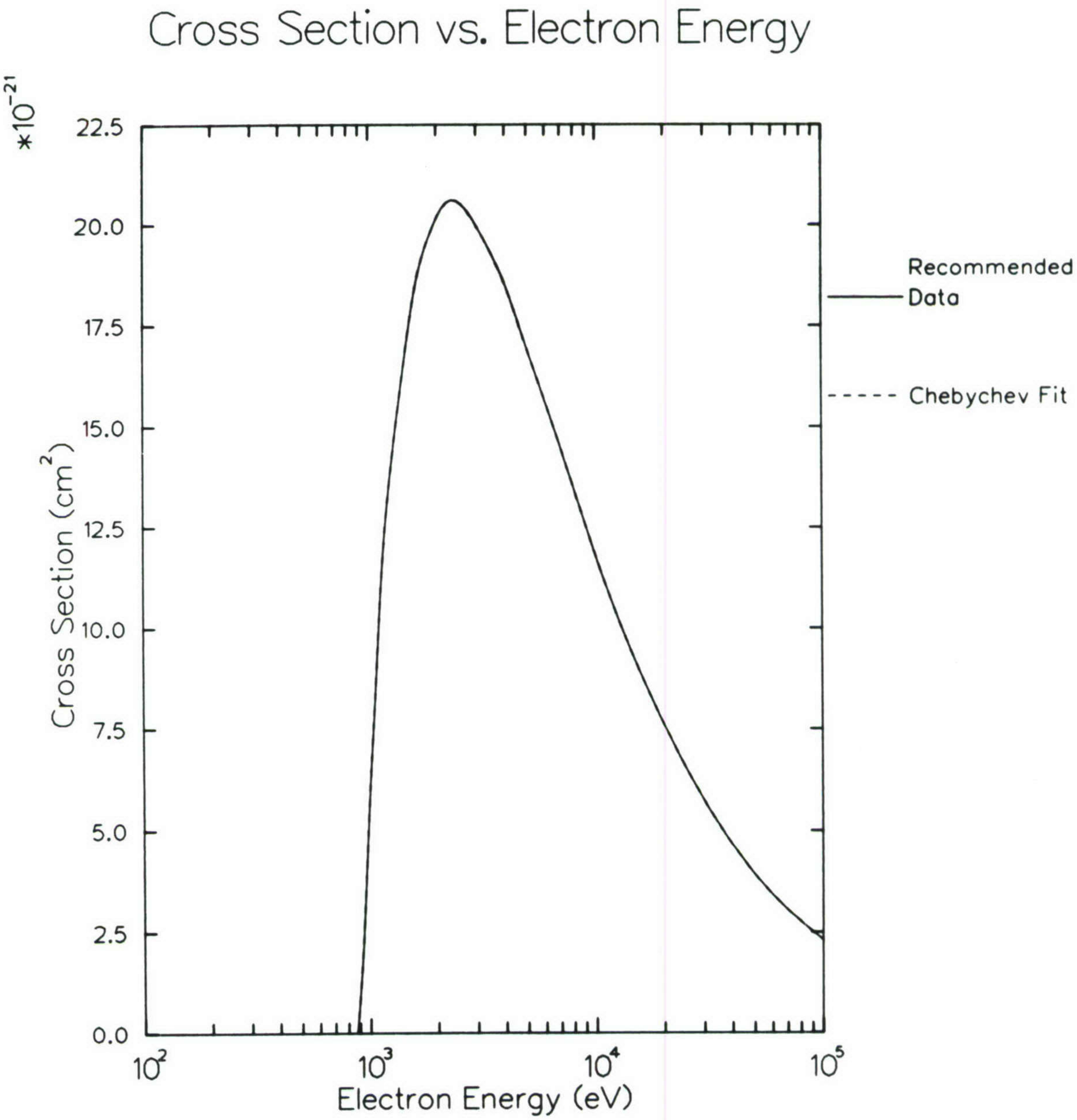
To within an rms deviation of 0.0% the following function can be used to represent the cross section using the parameters below,

Cross Section[cm^2] $= \frac{1}{IE}\left[A1\left(\ln\left(\frac{E}{I}\right)\right)\right]$, where $E \geq I$ (I = Ionization Potential = 871.4 eV)

Least Squares Fitting Parameters for Cross Sections

A1
4.2350E-13

$e^- + O^{7+} \rightarrow O^{8+} + 2e^-$



Electron-Impact Ionization Cross Sections for
$e^- + O^{q+} \rightarrow O^{(q+1)+} + 2e^-$

Maxwellian Rate Coefficients (cm^3/s)

e^- Temp. (eV)	O	O^+	O^{2+}	O^{3+}	O^{4+}	O^{5+}	O^{6+}	O^{7+}
1.0E+00	4.89E-15	1.60E-24	1.05E-32	0.00E+00**	0.00E+00**	0.00E+00**	0.00E+00**	0.00E+00**
2.0E+00	9.02E-12	1.29E-16	1.03E-20	1.20E-25	7.34E-33	0.00E+00**	0.00E+00**	0.00E+00**
4.0E+00	4.57E-10	1.31E-12	1.03E-14	1.70E-17	3.28E-21	8.38E-26	0.00E+00**	0.00E+00**
7.0E+00	2.97E-09	7.62E-11	3.98E-12	6.03E-14	3.35E-16	5.16E-19	0.00E+00**	0.00E+00**
1.0E+01	6.92E-09	4.12E-10	4.41E-11	1.72E-12	3.51E-14	2.73E-16	0.00E+00**	0.00E+00**
2.0E+01	2.19E-08	3.35E-09	7.78E-10	9.73E-11	9.00E-12	4.39E-13	2.81E-28	1.98E-31**
4.0E+01	4.46E-08	1.08E-08	3.58E-09	8.14E-10	1.67E-10	1.93E-11	1.32E-19	2.96E-21**
7.0E+01	6.35E-08	1.88E-08	7.28E-09	2.14E-09	6.25E-10	1.05E-10	7.42E-16	7.13E-17*
1.0E+02	7.40E-08	2.37E-08	9.83E-09	3.21E-09	1.09E-09	2.12E-10	2.49E-14	4.16E-15*
2.0E+02	8.80E-08	3.10E-08	1.40E-08	5.25E-09	2.12E-09	5.07E-10	1.74E-12	5.06E-13
4.0E+02	9.27E-08	3.41E-08	1.63E-08	6.61E-09	2.91E-09	8.16E-10	1.72E-11	5.98E-12
7.0E+02	9.06E-08	3.37E-08	1.66E-08	7.05E-09	3.22E-09	1.00E-09	4.97E-11	1.78E-11
1.0E+03	8.73E-08	3.24E-08	1.62E-08	7.06E-09	3.26E-09	1.07E-09	7.73E-11	2.78E-11
2.0E+03	7.76E-08	2.84E-08	1.45E-08	6.68E-09	3.11E-09	1.11E-09	1.29E-10	4.66E-11
4.0E+03	6.57E-08	2.35E-08	1.21E-08	5.97E-09	2.78E-09	1.04E-09	1.61E-10	5.85E-11
7.0E+03	5.61E-08	1.97E-08	1.02E-08	5.26E-09	2.45E-09	9.36E-10	1.68E-10	6.18E-11
1.0E+04	5.02E-08	1.74E-08	9.11E-09	4.77E-09	2.22E-09	8.59E-10	1.65E-10	6.13E-11
2.0E+04	3.84E-08	1.32E-08	6.96E-09	3.72E-09	1.74E-09	6.81E-10	1.46E-10	5.43E-11

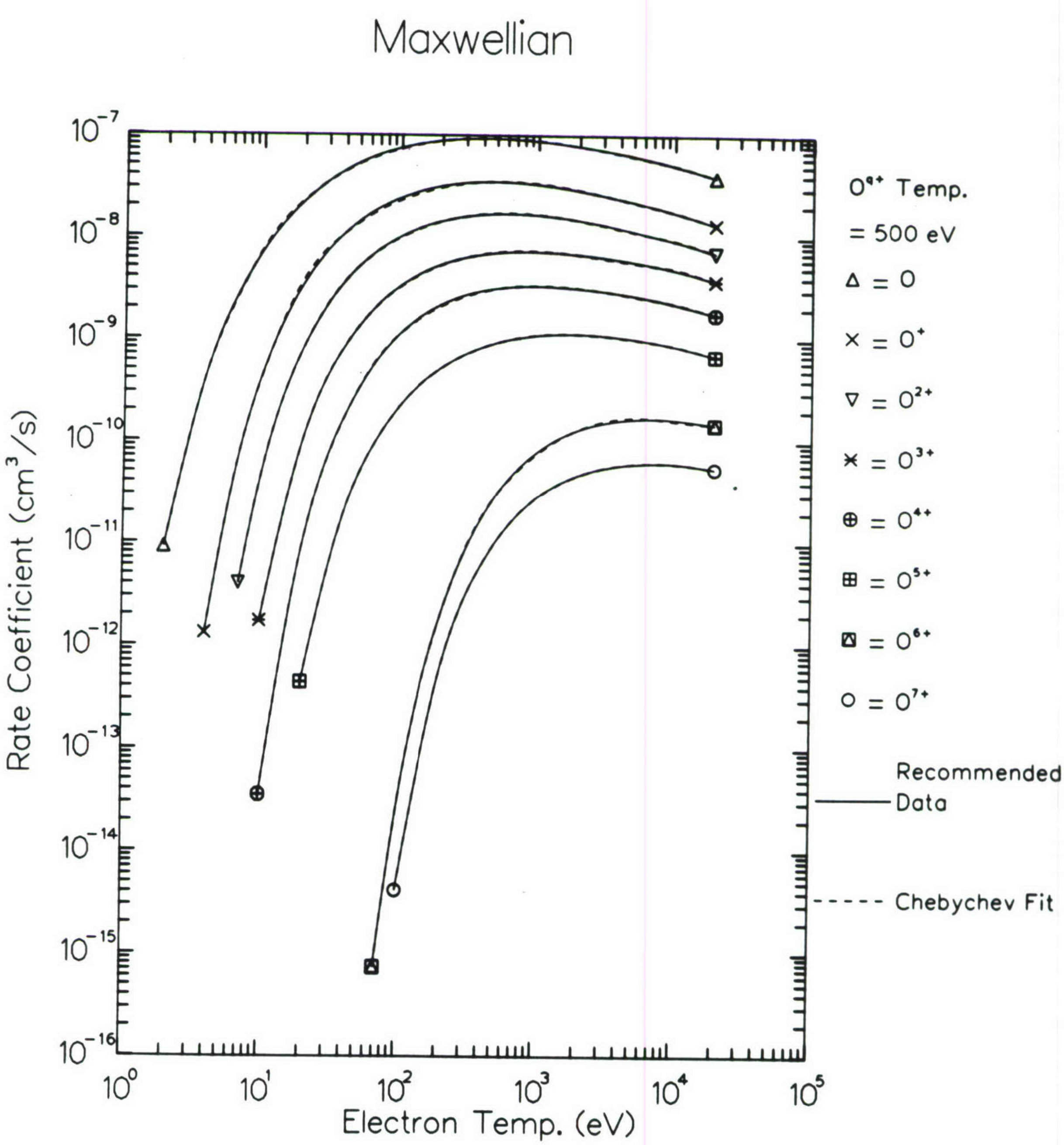
Accuracy: * - Possible Error Greater Than 10%
** - Possible Error Greater Than 100%

Chebychev Fitting Parameters for Rate Coefficients

	E_{min} (eV)	E_{max} (eV)	C1	C2	C3	C4	C5	C6	C7
O	2.0	2.0E+04	8.545E-08	2.968E-08	-3.108E-08	-1.195E-08	1.050E-08	1.441E-09	-2.961E-09
O^+	4.0	2.0E+04	3.070E-08	1.014E-08	-1.185E-08	-4.048E-09	4.210E-09	5.306E-10	-1.082E-09
O^{2+}	7.0	2.0E+04	1.570E-08	5.052E-09	-5.859E-09	-1.564E-09	2.057E-09	-2.466E-11	-5.828E-10
O^{3+}	10.	2.0E+04	7.188E-09	2.647E-09	-2.228E-09	-7.747E-10	7.428E-10	-2.183E-11	-2.569E-10
O^{4+}	10.	2.0E+04	3.172E-09	1.289E-09	-9.247E-10	-4.887E-10	3.291E-10	6.919E-11	-1.211E-10
O^{5+}	20.	2.0E+04	1.149E-09	4.779E-10	-2.924E-10	-1.522E-10	8.355E-11	1.442E-11	-2.487E-11
O^{6+}	70.	2.0E+04	1.631E-10	9.481E-11	-9.761E-12	-3.011E-11	-7.977E-13	8.986E-12	2.713E-12
O^{7+}	100.	2.0E+04	6.338E-11	3.510E-11	-4.581E-12	-9.662E-12	6.179E-13	1.714E-12	-5.642E-13

See appendix for Chebychev fit details.

$e^- + O^{q+} \rightarrow O^{(q+1)+} + 2e^-$



5. Excitation of C^{q+} and O^{q+} by Electron Impact

5.1 General Remarks 5-1

5.2 Rate Coefficients for Excitation of C^{q+} by Electron Impact 5-4

e + C^{+} (B-like): 5-4
- $2s^22p\ ^2P$ – $2s2p^2\ ^4P$ 5-4
- – $2s2p^2\ ^2S$ 5-4
- – $2s2p^2\ ^2D$ 5-6
- – $2s2p^2\ ^2P$ 5-6
- $2s2p^2\ ^4P$ – $2s2p^2\ ^2D$ 5-8
- – $2s2p^2\ ^2S$ 5-8
- – $2s2p^2\ ^2P$ 5-8
- $2s2p^2\ ^2D$ – $2s2p^2\ ^2S$ 5-10
- – $2s2p^2\ ^2P$ 5-10
- $2s2p^2\ ^2S$ – $2s2p^2\ ^2P$ 5-10

e + C^{2+} (Be-like): 5-12
- $2s^2\ ^1S$ – $2s2p\ ^3P$ 5-12
- – $2s2p\ ^1P$ 5-12
- – $2p^2\ ^3P$ 5-14
- – $2p^2\ ^1D$ 5-14
- – $2p^2\ ^1S$ 5-14
- $2s2p\ ^3P$ – $2s2p\ ^1P$ 5-16
- – $2p^2\ ^3P$ 5-16
- – $2p^2\ ^1D$ 5-18
- – $2p^2\ ^1S$ 5-18
- $2s2p\ ^1P$ – $2p^2\ ^3P$ 5-20
- – $2p^2\ ^1D$ 5-20
- – $2p^2\ ^1S$ 5-20
- $2p^2\ ^3P$ – $2p^2\ ^1D$ 5-22
- – $2p^2\ ^1S$ 5-22
- $2p^2\ ^1D$ – $2p^2\ ^1S$ 5-22

e + C^{3+} (Li-like): 5-24
- $2s\ ^2S$ – $2p\ ^2P$ 5-24
- – $3s\ ^2S$ 5-24
- – $3p\ ^2P$ 5-26
- – $3d\ ^2D$ 5-26

e + C^{4+} (He-like): 5-28
- $1s^2\ ^1S$ – $1s2s\ ^3S$ 5-28
- – $1s2s\ ^1S$ 5-28
- – $1s2p\ ^3P$ 5-30
- – $1s2p\ ^1P$ 5-30
- $1s2s\ ^3S$ – $1s2s\ ^1S$ 5-32
- – $1s2p\ ^3P$ 5-32
- – $1s2p\ ^1P$ 5-32
- $1s2s\ ^1S$ – $1s2p\ ^1P$ 5-34
- $1s2p\ ^3P$ – $1s2p\ ^1P$ 5-34

e + C^{5+} (H-like): 5-36
1s - 2s 5-36
1s - 2p 5-36
1s - 3s 5-38
1s - 3p 5-38
1s - 3d 5-38

5.3 Rate Coefficients for Excitation of O^{q+} by electron impact 5-40

e + O^{+} (N-like): 5-40
$2s^2 2p^3\ ^4S$ - $2s^2 2p^3\ ^2D$ 5-40
- $2s^2 2p^3\ ^2P$ 5-40
- $2s2p^4\ ^4P$ 5-42
- $2s^2 2p^2 3s\ ^4P$ 5-42
$2s^2 2p^3\ ^2D$ - $2s^2 2p^3\ ^2P$ 5-40

e + O^{2+} (C-like): 5-44
$2s^2 2p^2\ ^3P$ - $2s^2 2p^2\ ^1D$ 5-44
- $2s^2 2p^2\ ^1S$ 5-44
- $2s2p^3\ ^5S$ 5-46
- $2s2p^3\ ^1P$ 5-46
- $2s2p^3\ ^3D$ 5-48
- $2s2p^3\ ^3S$ 5-48
- $2s2p^3\ ^3P$ 5-50
- $2s2p^3\ ^1D$ 5-50
$2s^2 2p^2\ ^1D$ - $2s^2 2p^2\ ^1S$ 5-52
- $2s2p^3\ ^3D$ 5-52
- $2s2p^3\ ^3P$ 5-52
$2s^2 2p^2\ ^1S$ - $2s2p^3\ ^3D$ 5-54
- $2s2p^3\ ^3P$ 5-54
$2s2p^3\ ^3D$ - $2s2p^3\ ^3P$ 5-54
$2s2p^3\ ^5S$ - $2s2p^3\ ^3D$ 5-56
- $2s2p^3\ ^3P$ 5-56

e + O^{3+} (B-like): 5-58
$2s^2 2p\ ^2P$ - $2s2p^2\ ^4P$ 5-58
- $2s2p^2\ ^2P$ 5-58
- $2s2p^2\ ^2D$ 5-60
- $2s2p^2\ ^2S$ 5-60
$2s2p^2\ ^4P$ - $2s2p^2\ ^2D$ 5-62
- $2s2p^2\ ^2S$ 5-62
- $2s2p^2\ ^2P$ 5-62
$2s2p^2\ ^2D$ - $2s2p^2\ ^2S$ 5-64
- $2s2p^2\ ^2P$ 5-64
$2s2p^2\ ^2S$ - $2s2p^2\ ^2P$ 5-64

e + O^{4+} (Be-like): 5-66

$2s^2\ ^1S$ - $2s2p\ ^3P$ 5-66
- $2s2p\ ^1P$ 5-66
- $2p^2\ ^3P$ 5-66
- $2p^2\ ^1D$ 5-68
- $2p^2\ ^1S$ 5-68

$2s2p\ ^3P$ - $2s2p\ ^1P$ 5-70
- $2p^2\ ^3P$ 5-70
- $2p^2\ ^1D$ 5-72
- $2p^2\ ^1S$ 5-72

$2s2p\ ^1P$ - $2p^2\ ^3P$ 5-74
- $2p^2\ ^1D$ 5-74
- $2p^2\ ^1S$ 5-74

$2p^2\ ^3P$ - $2p^2\ ^1D$ 5-76
- $2p^2\ ^1S$ 5-76

$2p^2\ ^1D$ - $2p^2\ ^1S$ 5-76

e + O^{5+} (Li-like): 5-78

$2s\ ^2S$ - $2p\ ^2P$ 5-78
- $3s\ ^2S$ 5-78
- $3p\ ^2P$ 5-80
- $3d\ ^2D$ 5-80

e + O^{6+} (He-like): 5-82

$1s^2\ ^1S$ - $1s2s\ ^3S$ 5-82
- $1s2p\ ^3P$ 5-82
- $1s2s\ ^1S$ 5-84
- $1s2p\ ^1P$ 5-84

$1s2s\ ^3S$ - $1s2s\ ^1S$ 5-86
- $1s2p\ ^3P$ 5-86
- $1s2p\ ^1P$ 5-86

$1s2s\ ^1S$ - $1s2p\ ^1P$ 5-88

$1s2p\ ^3P$ - $1s2p\ ^1P$ 5-88

e + O^{7+} (H-like): 5-90

1s - 2s 5-90

1s - 2p 5-90

5. EXCITATION OF C^{q+} AND O^{q+} BY ELECTRON IMPACT

5.1 General Remarks

In this chapter, recommended rate coefficients are presented for the electron-impact excitation of carbon and oxygen atomic ions. Contributions to the total excitation rate are made by the following processes:

$$e^- + X_i^{q+} \rightarrow X_j^{q+} + e^- , \tag{5.1}$$

and

$$e^- + X_i^{q+} \rightarrow [X^{(q-1)+}]^* \longrightarrow X_j^{q+} + e^- , \tag{5.2}$$

where $i \rightarrow j$ is a transition between LS terms, q is the charge of the ion, and brackets indicate an autoionizing term. The resonant excitation process (5.2) is only important in the threshold region for excitation and produces a series of sharp resonances in the excitation cross section. For cases in which large resonance contributions are found, the rate coefficient will be strongly affected for temperatures $kT < E_{th}$, where E_{th} is the excitation threshold energy. At higher temperatures, $kT \gg E_{th}$, knowledge of the cross section for the direct excitation process (5.1) is sufficient to obtain an accurate rate coefficient.

Since very few experimental cross-section measurements of electron-impact excitation of C^{q+} and O^{q+} ions have been made, this compilation must rely almost exclusively on data from

theoretical calculations. The compilation of recommended data for carbon and oxygen ions by Itikawa et al. [G.34] forms the basis for the present analysis. In many cases, our recommended rate coefficients are identical to those of Itikawa et al., while other transitions have been re-analyzed in the light of additional data which have become available since 1982. The recent report on recommended excitation data by Aggarwal et al. [G.35] has been useful as a source of newer data, and for consistency checks.

Due to the pervading presence of sharp resonance structures in the excitation cross sections in the near-threshold energy region, and the prohibitive difficulty in accurately reproducing the complicated graphs from the original theoretical papers, we have elected in this compilation to present only rate coefficients calculated using a Maxwellian distribution of electron velocity. The effects of such resonances are included where available in the recommended rate coefficients. It is expected that for most fusion research applications excitation rate coefficients should be sufficient.

A large number of theoretical methods have been applied to the problem of the calculation of electron excitation cross sections for atomic ions. The most accurate will of course include resonance structures in the threshold region. In addition both the direct and resonance excitation processes (5.1) and (5.2) are in many cases strongly affected by

electron correlation corrections to the standard central-field model. These corrections may be divided into target-state correlations and scattering-channel coupling. Relativistic effects for the ground and first excited configurations of the carbon and oxygen ions are generally negligible. In most cases accurate LS close-coupling calculations including resonance effects are available over the threshold energy region, while LS distorted-wave or Coulomb-Born-Exchange calculations supplement the data at the higher incident electron energies. Thus by merging sets of theoretical cross section results, rate coefficients may be generated over a wide range of electron temperatures.

Chebychev polynomial fitting parameters are tabulated for each recommended reaction rate coefficients. Details for generating the rate coefficients from them are given in the Appendix, along with sample computer programs.

Electron-Impact Excitation Rate Coefficients for $e^- + C^+$ (B-like)

Maxwellian Rate Coefficients (cm^3/s)

e^- Temp. (eV)	$2s^22p\ ^2P - 2s2p^2\ ^2S$ (E_{th} = 12.0 eV)	$2s^22p\ ^2P - 2s2p^2\ ^4P$ (E_{th} = 5.33 eV)
1.0E+00		2.07E-10
2.0E+00	5.21E-11	2.04E-09
4.0E+00	8.59E-10	5.23E-09
7.0E+00	2.79E-09	6.61E-09
1.0E+01	4.44E-09	6.61E-09
2.0E+01	7.56E-09	5.26E-09
4.0E+01	9.60E-09	3.34E-09
7.0E+01	1.03E-08	2.04E-09
1.0E+02	1.03E-08	1.42E-09
2.0E+02	9.80E-09	6.38E-10
4.0E+02	8.76E-09	2.61E-10
7.0E+02	7.76E-09	1.21E-10
1.0E+03	7.11E-09	7.31E-11
2.0E+03	5.87E-09	
4.0E+03	4.75E-09	
7.0E+03	3.96E-09	
1.0E+04	3.51E-09	
2.0E+04	2.75E-09	
Accuracy:	30%	30%

References: T.77, T.78, T.79, T.80, T.82 T.83

Note: The recommended excitation-rate data for C^+ from the compilation [T.77] were based on close-coupling and Coulomb-Born-Exchange calculations [T.79, T.80]. This work has been updated to take into account a number of recent multi-term close-coupling calculations [T.81, T.82, T.83] which have been recommended in compilation [T.78].

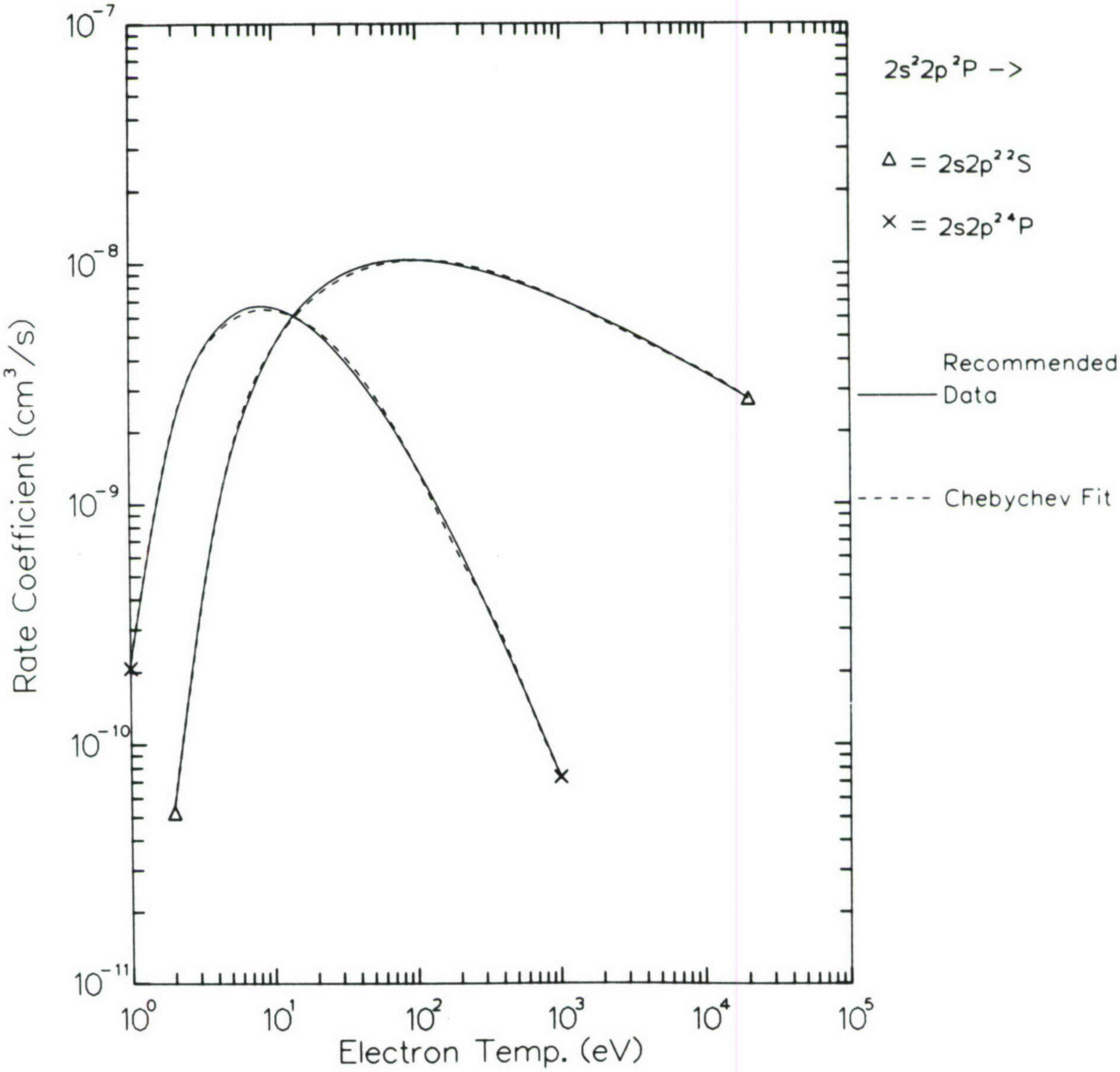
Chebychev Fitting Parameters for Rate Coefficients

E_{min} (eV)	E_{max} (eV)	C1	C2	C3	C4	C5	C6	C7
($2s^22p\ ^2P - 2s2p^2\ ^2S$								
2.0	2.0E+04	9.51369E-09	1.02084E-09	-4.34716E-09	9.47942E-10	9.19992E-10	-6.23666E-10	6.75934E-11
($2s^22p\ ^2P - 2s2p^2\ ^4P$)								
1.0	1.0E+03	4.08436E-09	-1.18465E-09	-2.25174E-09	1.75177E-09	1.10461E-10	-6.33900E-10	2.39268E-10

See appendix for Chebychev fit details.

$e^- + C^+$ (B-like)

Maxwellian Excitation Rate Coefficients



Electron-Impact Excitation Rate Coefficients for
$e^- + C^+$ (B-like)

Maxwellian Rate Coefficients (cm^3/s)

e^- Temp. (eV)	$2s^22p\ ^2P - 2s2p^2\ ^2P$ (E_{th} = 13.7 eV)	$2s^22p\ ^2P - 2s2p^2\ ^2D$ (E_{th} = 9.29 eV)
2.0E+00	5.29E-11	5.91E-10
4.0E+00	1.45E-09	4.93E-09
7.0E+00	6.01E-09	1.17E-08
1.0E+01	1.07E-08	1.61E-08
2.0E+01	2.11E-08	2.27E-08
4.0E+01	2.93E-08	2.58E-08
7.0E+01	3.30E-08	2.61E-08
1.0E+02	3.40E-08	2.57E-08
2.0E+02	3.34E-08	2.37E-08
4.0E+02	3.06E-08	2.10E-08
7.0E+02	2.76E-08	1.85E-08
1.0E+03	2.55E-08	1.70E-08
2.0E+03	2.13E-08	1.40E-08
4.0E+03	1.74E-08	1.14E-08
7.0E+03	1.46E-08	9.50E-09
1.0E+04	1.30E-08	8.43E-09
2.0E+04	1.03E-08	6.62E-09
Accuracy:	30%	30%

References: T.77, T.78, T.79, T.80, T.82 T.83

Note: The recommended excitation-rate data for C^+ from the compilation [T.77] were based on close-coupling and Coulomb-Born-Exchange calculations [T.79, T.80]. This work has been updated to take into account a number of recent multi-term close-coupling calculations [T.81, T.82, T.83] which have been recommended in compilation [T.78].

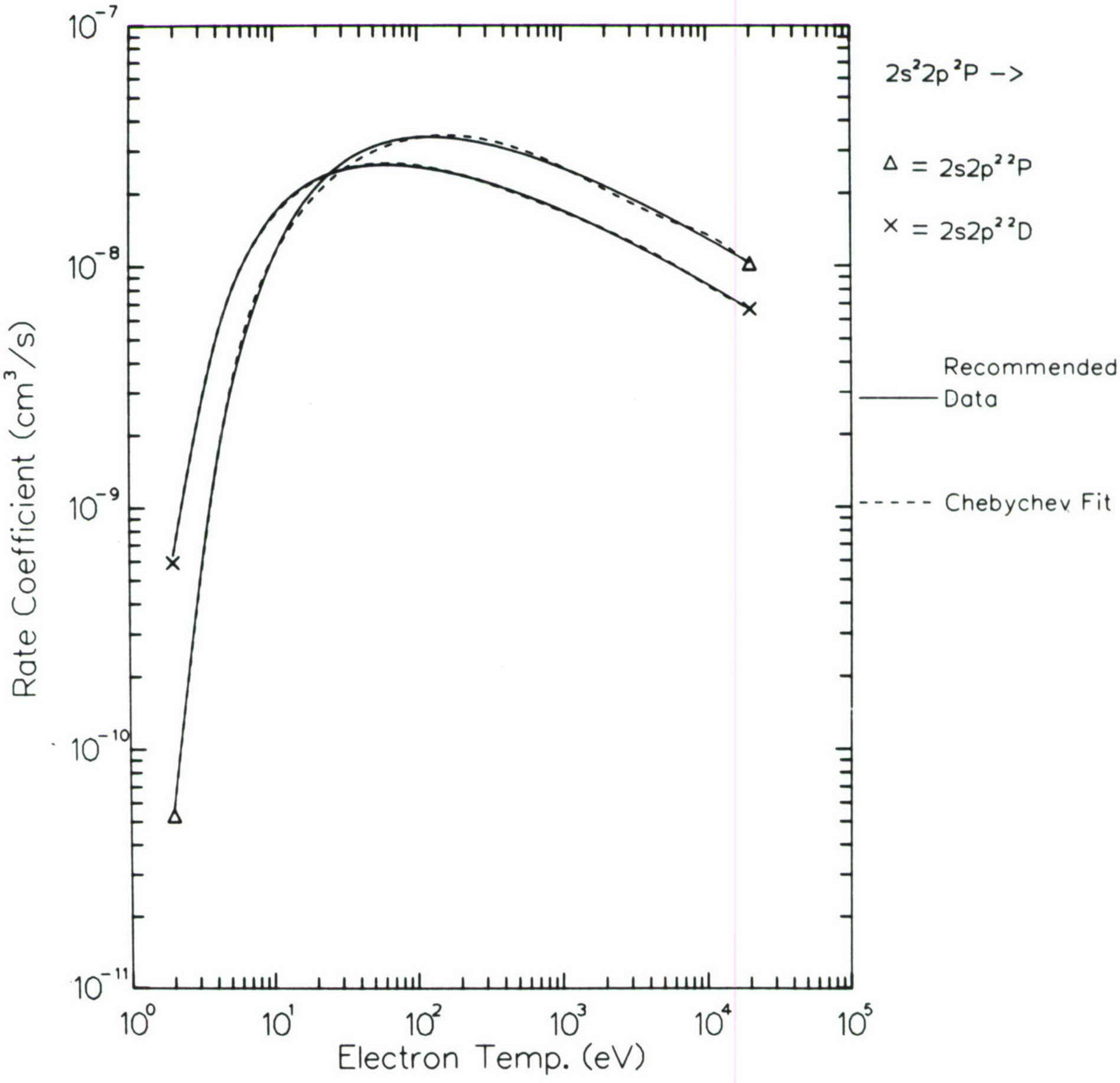
Chebychev Fitting Parameters for Rate Coefficients

E_{min} (eV)	E_{max} (eV)	C1	C2	C3	C4	C5	C6	C7
($2s^22p\ ^2P - 2s2p^2\ ^2P$)								
2.0	2.0E+04	3.13868E-08	5.38986E-09	-1.41416E-08	1.37220E-09	4.08818E-09	-1.70755E-09	-5.32505E-10
($2s^22p\ ^2P - 2s2p^2\ ^2D$)								
2.0	2.0E+04	2.54183E-08	7.33513E-10	-1.07906E-08	3.81060E-09	1.00180E-09	-1.51893E-09	6.96106E-10

See appendix for Chebychev fit details.

$e^- + C^+$ (B-like)

Maxwellian Excitation Rate Coefficients



Electron-Impact Excitation Rate Coefficients for $e^- + C^+$ (B-like)

Maxwellian Rate Coefficients (cm^3/s)

e^- Temp. (eV)	$2s2p^2\ ^4P - 2s2p^2\ ^2D$ (E_{th} = 3.96 eV)	$2s2p^2\ ^4P - 2s2p^2\ ^2P$ (E_{th} = 8.38 eV)	$2s2p^2\ ^4P - 2s2p^2\ ^2S$ (E_{th} = 6.63 eV)
1.0E+00	6.77E-10	2.03E-12	5.14E-12
2.0E+00	3.59E-09	9.37E-11	1.09E-10
4.0E+00	6.85E-09	5.15E-10	4.23E-10
7.0E+00	7.60E-09	8.84E-10	6.43E-10
1.0E+01	7.14E-09	9.78E-10	6.85E-10
2.0E+01	5.10E-09	8.30E-10	5.62E-10
4.0E+01	2.92E-09	5.09E-10	3.40E-10
7.0E+01	1.65E-09	2.93E-10	1.95E-10
1.0E+02	1.09E-09	1.96E-10	1.29E-10
2.0E+02	4.45E-10	8.24E-11	5.38E-11
4.0E+02	1.64E-10	3.22E-11	2.08E-11
7.0E+02	7.04E-11	1.45E-11	9.36E-12
1.0E+03	4.07E-11	8.68E-12	5.57E-12
Accuracy:	50%	50%	50%

References: T.77, T.78, T.79, T.80, T.82 T.83

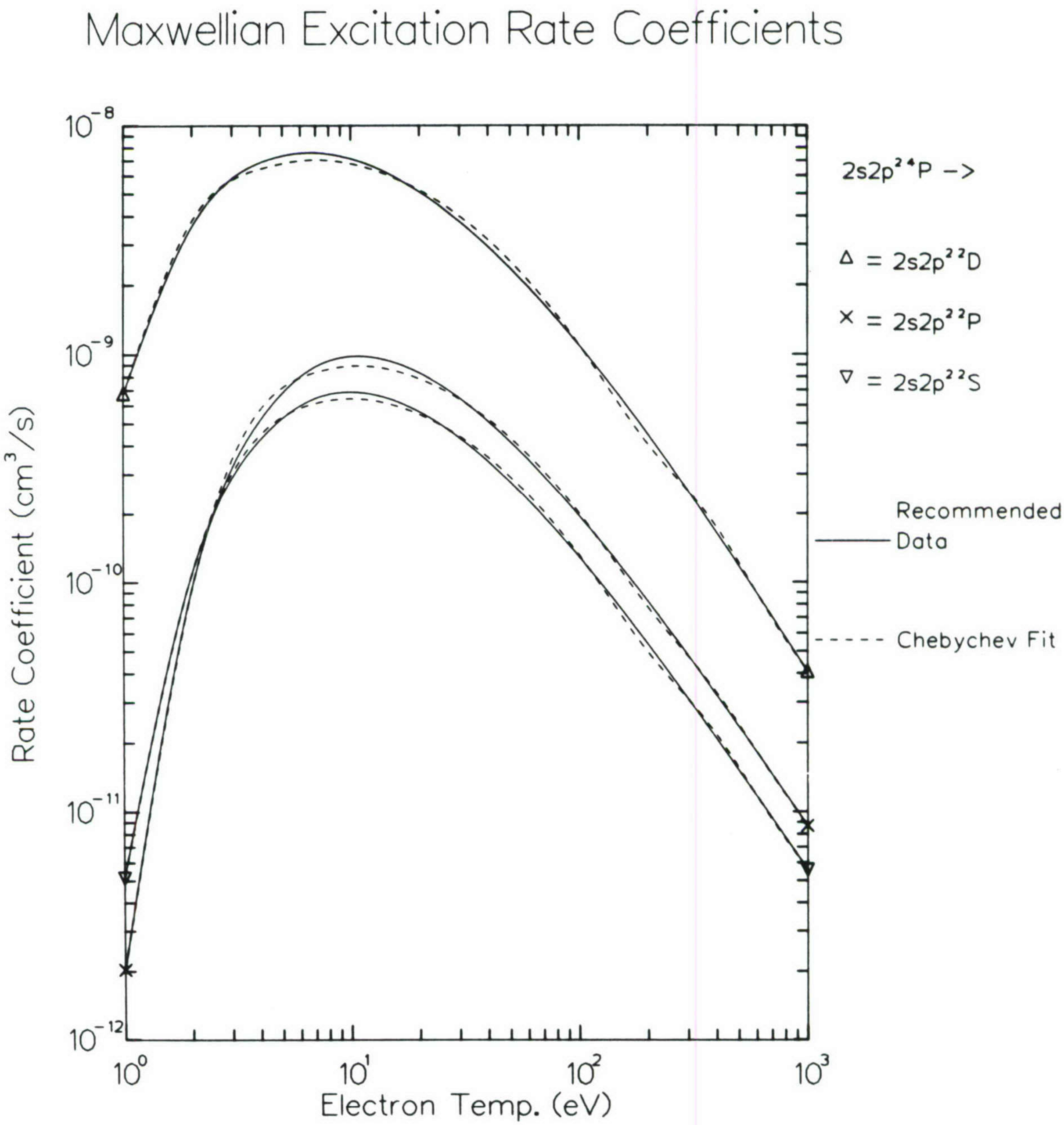
Note: The recommended excitation-rate data for C^+ from the compilation [T.77] were based on close-coupling and Coulomb-Born-Exchange calculations [T.79, T.80]. This work has been updated to take into account a number of recent multi-term close-coupling calculations [T.81, T.82, T.83] which have been recommended in compilation [T.78].

Chebychev Fitting Parameters for Rate Coefficients

E_{min} (eV)	E_{max} (eV)	C1	C2	C3	C4	C5	C6	C7
($2s2p^2\ ^4P - 2s2p^2\ ^2D$)								
1.0	1.0E+03	4.79474E-09	-1.93305E-09	-1.93722E-09	2.05861E-09	-3.05778E-10	-4.42668E-10	2.03564E-10
($2s2p^2\ ^4P - 2s2p^2\ ^2P$)								
1.0	1.0E+03	4.86429E-10	-9.65723E-11	-3.46726E-10	2.22912E-10	6.74896E-11	-1.23008E-10	4.13837E-11
($2s2p^2\ ^4P - 2s2p^2\ ^2S$)								
1.0	1.0E+03	3.59881E-10	-8.56598E-11	-2.38552E-10	1.68620E-10	3.45516E-11	-8.27364E-11	2.94248E-11

See appendix for Chebychev fit details.

$e^- + C^+$ (B-like)


Maxwellian Excitation Rate Coefficients
Rate Coefficient (cm³/s)
Electron Temp. (eV)
10⁻⁸
10⁻⁹
10⁻¹⁰
10⁻¹¹
10⁻¹²
10⁰
10¹
10²
10³
2s2p² ⁴P ->
Δ = 2s2p² ²D
× = 2s2p² ²P
∇ = 2s2p² ²S
Recommended Data
Chebychev Fit

Electron-Impact Excitation Rate Coefficients for $e^- + C^+$ (B-like)

Maxwellian Rate Coefficients (cm^3/s)

e^- Temp. (eV)	$2s2p^2\ ^2D - 2s2p^2\ ^2S$ (E_{th} = 2.67 eV)	$2s2p^2\ ^2D - 2s2p^2\ ^2P$ (E_{th} = 4.43 eV)	$2s2p^2\ ^2S - 2s2p^2\ ^2P$ (E_{th} = 1.75 eV)
1.0E+00	9.17E-10	2.68E-10	2.12E-09
2.0E+00	2.53E-09	1.75E-09	3.90E-09
4.0E+00	3.58E-09	3.82E-09	4.56E-09
7.0E+00	3.70E-09	4.57E-09	4.25E-09
1.0E+01	3.54E-09	4.46E-09	3.80E-09
2.0E+01	3.03E-09	3.42E-09	2.67E-09
4.0E+01	2.48E-09	2.13E-09	1.62E-09
7.0E+01	2.08E-09	1.29E-09	9.92E-10
1.0E+02	1.86E-09	9.02E-10	7.02E-10
2.0E+02	1.48E-09	4.11E-10	3.31E-10
4.0E+02	1.17E-09		1.41E-10
7.0E+02	9.67E-10		6.66E-11
1.0E+03	8.52E-10		4.05E-11
Accuracy:	50%	50%	50%

References: T.77, T.78, T.79, T.80, T.82 T.83

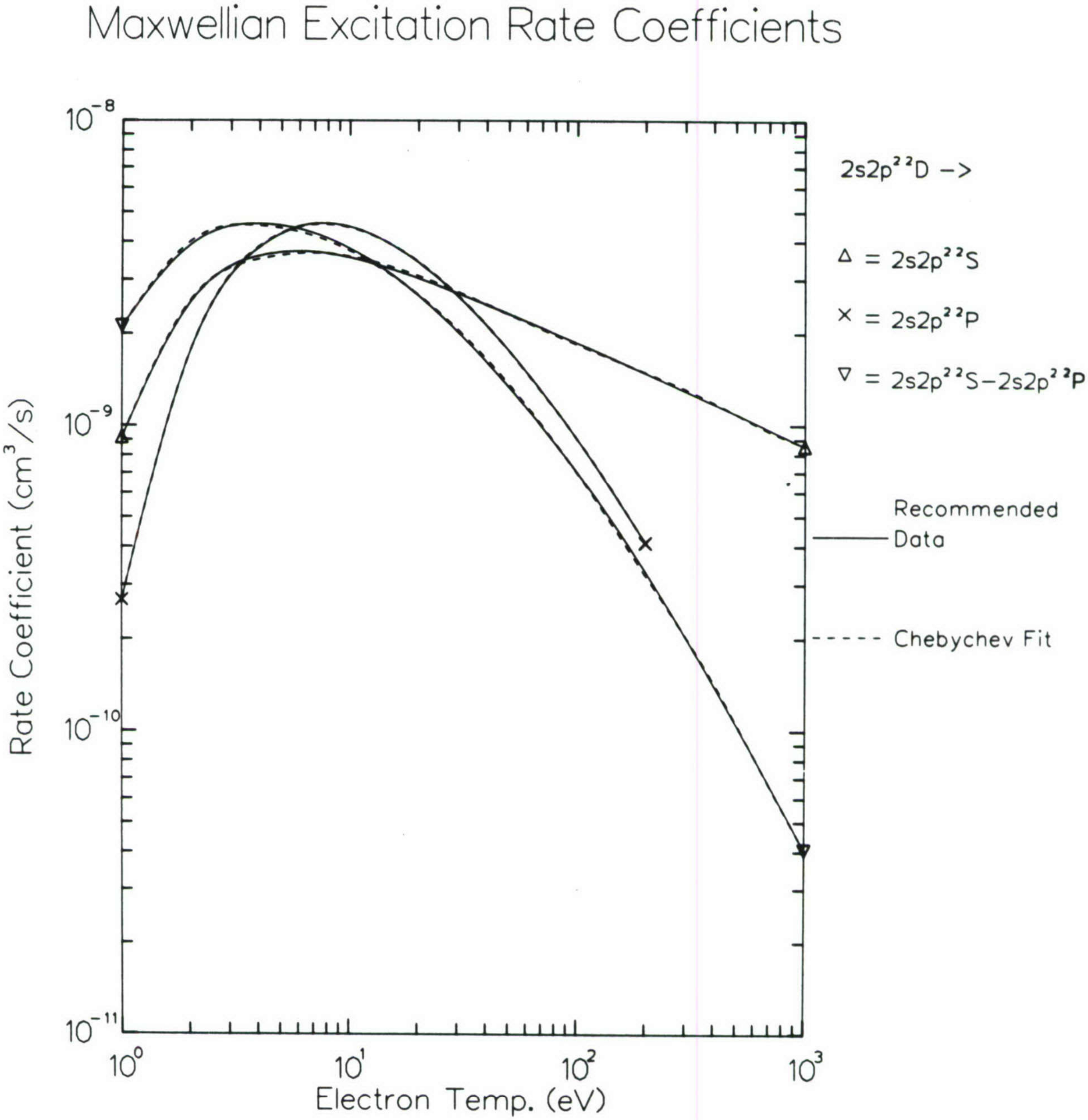
Note: The recommended excitation-rate data for C^+ from the compilation [T.77] were based on close-coupling and Coulomb-Born-Exchange calculations [T.79, T.80]. This work has been updated to take into account a number of recent multi-term close-coupling calculations [T.81, T.82, T.83] which have been recommended in compilation [T.78].

Chebychev Fitting Parameters for Rate Coefficients

E_{min} (eV)	E_{max} (eV)	C1	C2	C3	C4	C5	C6	C7
($2s2p^2\ ^2D - 2s2p^2\ ^2S$)								
1.0	1.0E+03	3.94967E-09	-6.75864E-10	-9.54244E-10	6.94181E-10	-1.87906E-10	-4.80112E-11	5.32755E-11
($2s2p^2\ ^2D - 2s2p^2\ ^2P$)								
1.0	2.0E+02	3.69422E-09	-3.37144E-10	-1.90422E-09	7.07264E-10	3.37409E-10	-2.98803E-10	5.89365E-11
($2s2p^2\ ^2S - 2s2p^2\ ^2P$)								
1.0	1.0E+03	3.80191E-09	-2.01105E-09	-4.85054E-10	9.83713E-10	-3.71698E-10	-8.35466E-12	3.20897E-11

See appendix for Chebychev fit details.

$e^- + C^+$ (B-like)



Maxwellian Excitation Rate Coefficients
10^-8
10^-9
10^-10
10^-11
Rate Coefficient (cm^3/s)
10^0
10^1
10^2
10^3
Electron Temp. (eV)
2s2p^2 2D ->
Δ = 2s2p^2 2S
× = 2s2p^2 2P
∇ = 2s2p^2 2S-2s2p^2 2P
Recommended Data
Chebychev Fit

Electron-Impact Excitation Rate Coefficients for
$e^- + C^{2+}$ (Be-like)

Maxwellian Rate Coefficients (cm^3/s)

e^- Temp. (eV)	$2s^2\ ^1S - 2s2p\ ^1P$ (E_{th} = 12.7 eV)	$2s^2\ ^1S - 2s2p\ ^3P$ (E_{th} = 6.50 eV)
1.0E+00		1.17E-10
2.0E+00	4.09E-10	2.23E-09
4.0E+00	7.27E-09	7.76E-09
7.0E+00	2.29E-08	1.06E-08
1.0E+01	3.48E-08	1.06E-08
2.0E+01	5.37E-08	8.05E-09
4.0E+01	6.29E-08	4.89E-09
7.0E+01	6.47E-08	2.93E-09
1.0E+02	6.41E-08	2.02E-09
2.0E+02	6.01E-08	
4.0E+02	5.39E-08	
7.0E+02	4.82E-08	
1.0E+03	4.43E-08	
Accuracy:	20%	30%

References: T.77, T.78, T.79, T.80, T.84, T.85, T.86

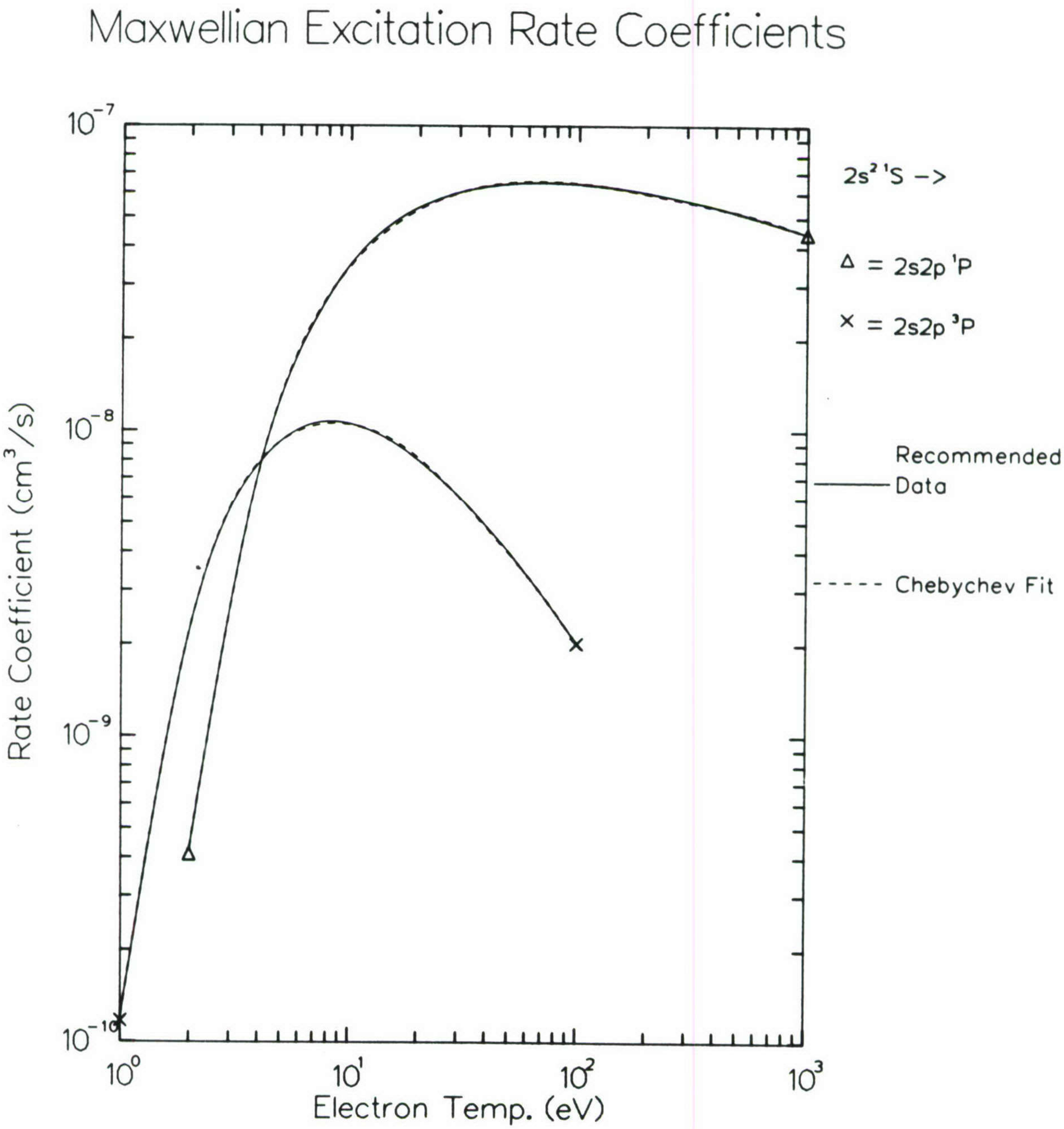
Note: The recommended excitation rate data for C^{2+} from the compilation [T.77] were based on close-coupling [T.85, T.86], distorted-wave, and Coulomb-Born-Exchange [T.79, T.80] calculations. This work has been updated to take into account recent 12-term close-coupling calculations [T.84] which have been recommended in compilation [T.78].

Chebychev Fitting Parameters for Rate Coefficients

E_{min} (eV)	E_{max} (eV)	C1	C2	C3	C4	C5	C6	C7
($2s^2\ ^1S - 2s2p\ ^1P$)								
2.0	1.0E+03	7.64258E-08	2.53399E-08	-2.06993E-08	-1.51541E-09	4.94553E-09	-1.93370E-09	-1.59140E-10
($2s^2\ ^1S - 2s2p\ ^3P$)								
1.0	1.0E+02	8.77848E-09	1.11786E-09	-4.68714E-09	3.75093E-10	1.39982E-09	-5.40217E-10	-3.22647E-11

See appendix for Chebychev fit details.

$e^- + C^{2+}$ (Be-like)


Maxwellian Excitation Rate Coefficients
Rate Coefficient (cm³/s)
Electron Temp. (eV)
10⁻⁷
10⁻⁸
10⁻⁹
10⁻¹⁰
10⁰
10¹
10²
10³
2s² ¹S ->
Δ = 2s2p ¹P
× = 2s2p ³P
Recommended Data
Chebychev Fit

Electron-Impact Excitation Rate Coefficients for $e^- + C^{2+}$ (Be-like)

Maxwellian Rate Coefficients (cm^3/s)

e^- Temp. (eV)	$2s^2\ {}^1S - 2p^2\ {}^1D$ (E_{th} = 18.1 eV)	$2s^2\ {}^1S - 2p^2\ {}^1S$ (E_{th} = 22.6 eV)	$2s^2\ {}^1S - 2p^2\ {}^3P$ (E_{th} = 17.0 eV)
2.0E+00	2.56E-12		3.01E-13
4.0E+00	1.65E-10	1.04E-11	1.53E-11
7.0E+00	8.49E-10	9.18E-11	7.13E-11
1.0E+01	1.52E-09	2.10E-10	1.18E-10
2.0E+01	2.54E-09	5.01E-10	1.60E-10
4.0E+01	2.68E-09	6.42E-10	1.17E-10
7.0E+01	2.36E-09	6.10E-10	6.37E-11
1.0E+02	2.09E-09	5.70E-10	3.47E-11
2.0E+02	1.55E-09	5.17E-10	
4.0E+02	1.12E-09	4.40E-10	
7.0E+02	8.48E-10	3.67E-10	
1.0E+03	7.09E-10	3.22E-10	
Accuracy:	50%	50%	50%

References: T.77, T.78, T.79, T.80, T.84, T.85, T.86

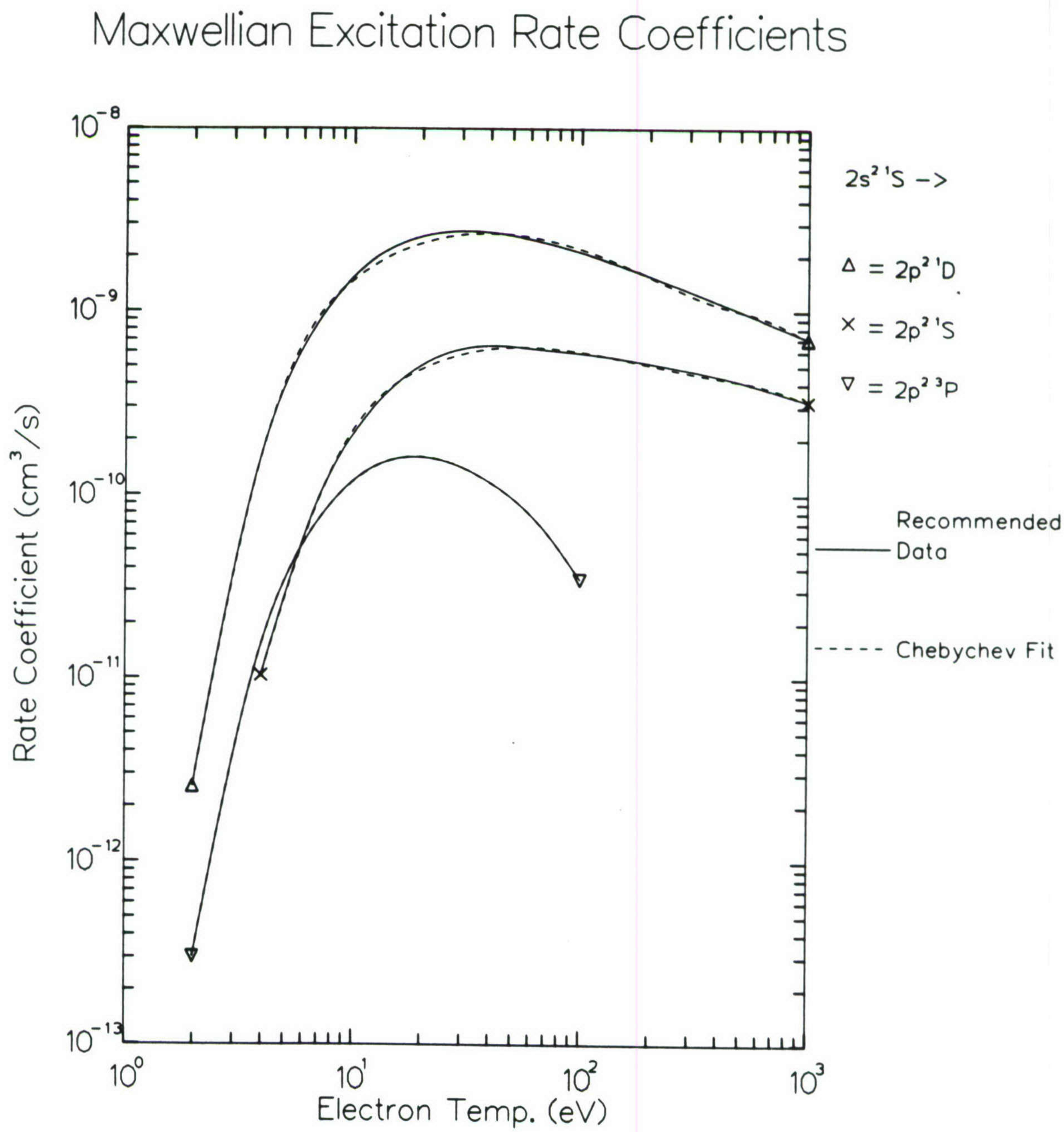
Note: The recommended excitation rate data for C^{2+} from the compilation [T.77] were based on close-coupling [T.85, T.86], distorted-wave, and Coulomb-Born-Exchange [T.79, T.80] calculations. This work has been updated to take into account recent 12-term close-coupling calculations [T.84] which have been recommended in compilation [T.78].

Chebychev Fitting Parameters for Rate Coefficients

E_{min} (eV)	E_{max} (eV)	C1	C2	C3	C4	C5	C6	C7
($2s^2\ {}^1S - 2p^2\ {}^1D$)								
2.0	1.0E+03	2.23679E-09	4.06527E-10	-1.09631E-09	7.83299E-11	3.76115E-10	-1.35714E-10	-4.64997E-11
($2s^2\ {}^1S - 2p^2\ {}^1S$)								
4.0	1.0E+03	6.96118E-10	1.62425E-10	-2.31755E-10	2.58107E-11	4.82342E-11	-3.38534E-11	1.97821E-13
($2s^2\ {}^1S - 2p^2\ {}^3P$)								
2.0	1.0E+02	1.30272E-10	3.43722E-11	-6.08533E-11	-2.23889E-11	1.87605E-11	5.22541E-12	-5.53333E-12

See appendix for Chebychev fit details.

$e^- + C^{2+}$ (Be-like)



Maxwellian Excitation Rate Coefficients
Rate Coefficient (cm³/s)
Electron Temp. (eV)
10⁻⁸
10⁻⁹
10⁻¹⁰
10⁻¹¹
10⁻¹²
10⁻¹³
10⁰
10¹
10²
10³
2s² ¹S ->
Δ = 2p² ¹D
× = 2p² ¹S
∇ = 2p² ³P
Recommended Data
Chebychev Fit

Electron-Impact Excitation Rate Coefficients for $e^- + C^{2+}$ (Be-like)

Maxwellian Rate Coefficients (cm^3/s)

e^- Temp. (eV)	$2s2p\ ^3P - 2p^2\ ^3P$ (E_{th} = 10.5 eV)	$2s2p\ ^3P - 2s2p\ ^1P$ (E_{th} = 6.19 eV)
1.0E+00	5.15E-12	6.22E-11
2.0E+00	6.93E-10	9.18E-10
4.0E+00	6.82E-09	2.71E-09
7.0E+00	1.65E-08	3.34E-09
1.0E+01	2.26E-08	3.14E-09
2.0E+01	3.11E-08	2.10E-09
4.0E+01	3.45E-08	1.13E-09
7.0E+01	3.46E-08	6.34E-10
1.0E+02	3.37E-08	4.32E-10
2.0E+02	3.06E-08	
4.0E+02	2.66E-08	
7.0E+02	2.31E-08	
1.0E+03	2.10E-08	
Accuracy:	50%	50%

References: T.77, T.78, T.79, T.80, T.84, T.85, T.86

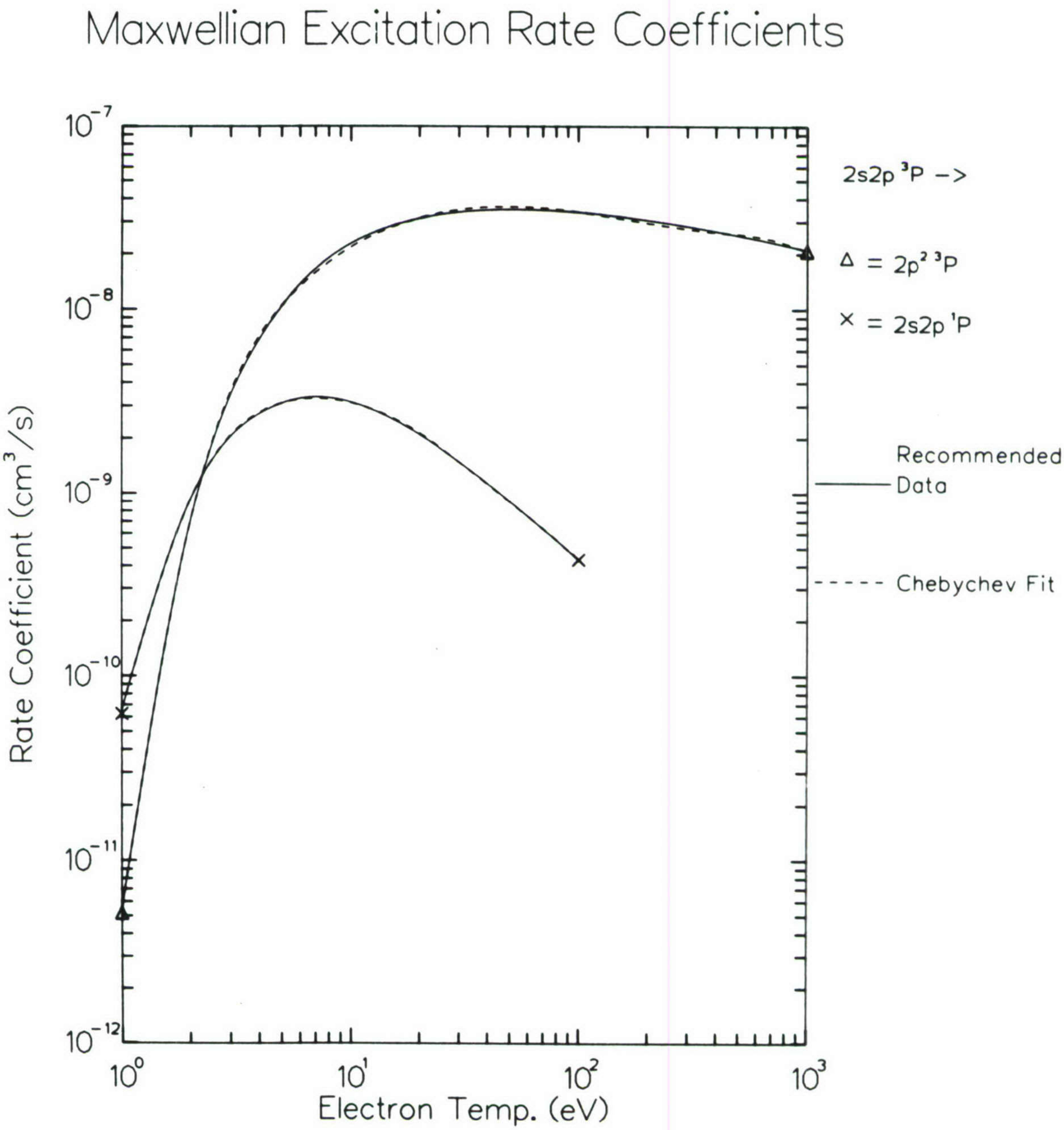
Note: The recommended excitation rate data for C^{2+} from the compilation [T.77] were based on close-coupling [T.85, T.86], distorted-wave, and Coulomb-Born-Exchange [T.79, T.80] calculations. This work has been updated to take into account recent 12-term close-coupling calculations [T.84] which have been recommended in compilation [T.78].

Chebychev Fitting Parameters for Rate Coefficients

E_{min} (eV)	E_{max} (eV)	C1	C2	C3	C4	C5	C6	C7
($2s2p\ ^3P - 2p^2\ ^3P$)								
1.0	1.0E+03	3.73486E-08	1.35509E-08	-1.11640E-08	-2.58433E-09	3.94049E-09	-6.32749E-10	-1.11172E-09
($2s2p\ ^3P - 2s2p\ ^1P$)								
1.0	1.0E+02	2.54562E-09	9.53341E-11	-1.45837E-09	3.31419E-10	4.06463E-10	-2.42120E-10	2.59141E-11

See appendix for Chebychev fit details.

$e^- + C^{2+}$ (Be-like)


Maxwellian Excitation Rate Coefficients
10^-7
10^-8
10^-9
10^-10
10^-11
10^-12
Rate Coefficient (cm^3/s)
10^0
10^1
10^2
10^3
Electron Temp. (eV)
2s2p ^3P ->
Δ = 2p^2 ^3P
× = 2s2p ^1P
Recommended Data
Chebychev Fit

Electron-Impact Excitation Rate Coefficients for $e^- + C^{2+}$ (Be-like)

Maxwellian Rate Coefficients (cm^3/s)

e^- Temp. (eV)	$2s2p\ ^3P - 2p^2\ ^1D$ (E_{th} = 11.6 eV)	$2s2p\ ^3P - 2p^2\ ^1S$ (E_{th} = 16.1 eV)
1.0E+00	1.09E-13	
2.0E+00	2.49E-11	3.99E-13
4.0E+00	3.07E-10	1.43E-11
7.0E+00	7.55E-10	5.08E-11
1.0E+01	9.82E-10	8.17E-11
2.0E+01	1.08E-09	1.19E-10
4.0E+01	8.75E-10	9.81E-11
7.0E+01	6.62E-10	7.99E-11
1.0E+02	5.42E-10	6.65E-11
2.0E+02	3.62E-10	4.81E-11
4.0E+02	2.43E-10	3.39E-11
7.0E+02	1.78E-10	2.54E-11
1.0E+03	1.47E-10	2.12E-11
Accuracy:	50%	50%

References: T.77, T.78, T.79, T.80, T.84, T.85, T.86

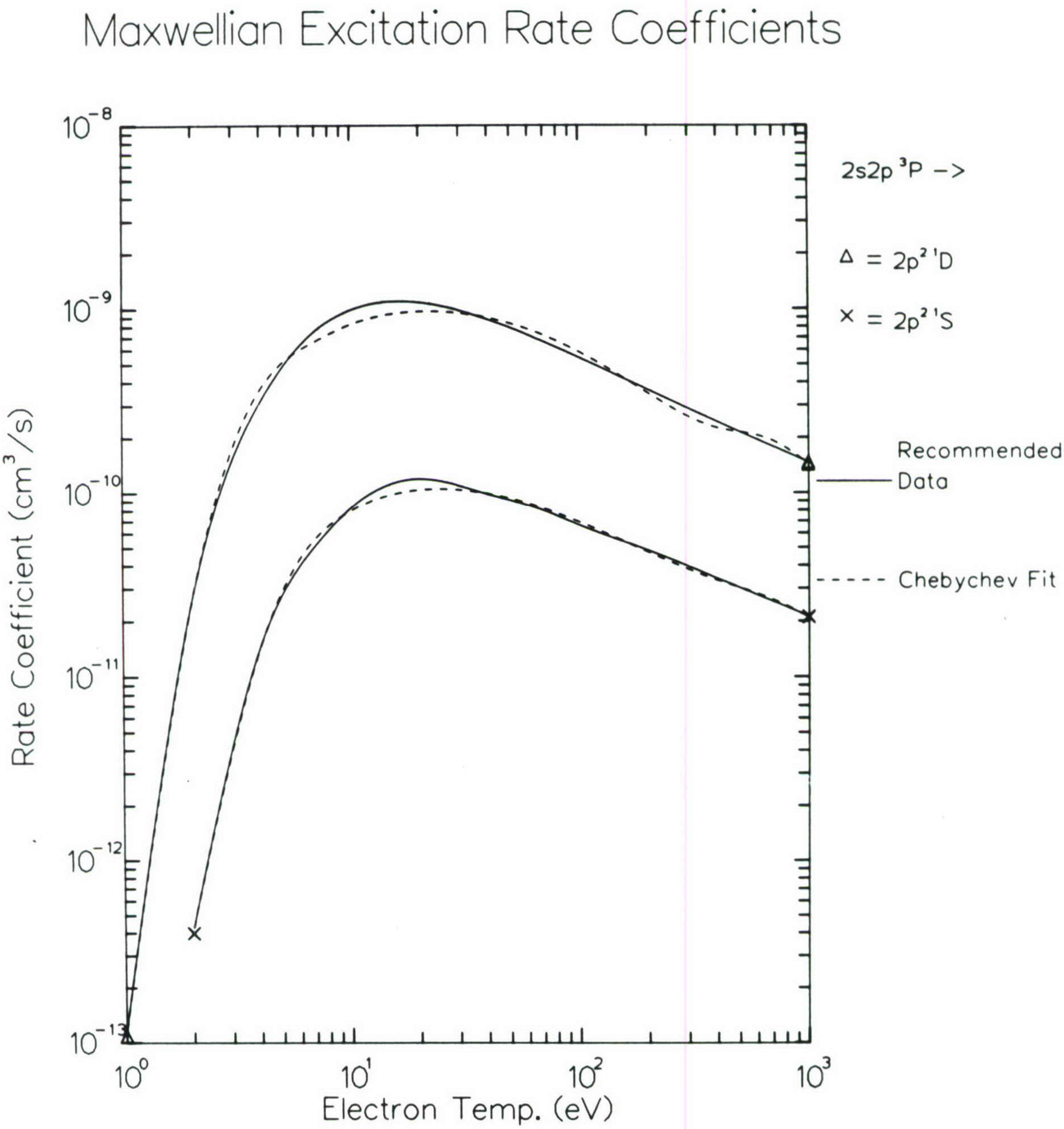
Note: The recommended excitation rate data for C^{2+} from the compilation [T.77] were based on close-coupling [T.85, T.86], distorted-wave, and Coulomb-Born-Exchange [T.79, T.80] calculations. This work has been updated to take into account recent 12-term close-coupling calculations [T.84] which have been recommended in compilation [T.78].

Chebychev Fitting Parameters for Rate Coefficients

E_{min} (eV)	E_{max} (eV)	C1	C2	C3	C4	C5	C6	C7
($2s2p\ ^3P - 2p^2\ ^1D$)								
1.0	1.0E+03	7.03133E-10	6.25362E-11	-4.17746E-10	8.03601E-11	1.54720E-10	-7.14620E-11	-1.69981E-11
($2s2p\ ^3P - 2p^2\ ^1S$)								
2.0	1.0E+03	8.47935E-11	6.35177E-12	-4.44425E-11	1.35435E-11	1.10077E-11	-9.59855E-12	1.73369E-12

See appendix for Chebychev fit details.

$e^- + C^{2+}$ (Be-like)


Maxwellian Excitation Rate Coefficients
Rate Coefficient (cm³/s)
Electron Temp. (eV)
2s2p ³P ->
Δ = 2p² ¹D
× = 2p² ¹S
Recommended Data
Chebychev Fit
10⁻⁸
10⁻⁹
10⁻¹⁰
10⁻¹¹
10⁻¹²
10⁻¹³
10⁰
10¹
10²
10³

Electron-Impact Excitation Rate Coefficients for $e^- + C^{2+}$ (Be-like)

Maxwellian Rate Coefficients (cm^3/s)

e^- Temp. (eV)	$2s2p\ ^1P - 2p^2\ ^1D$ (E_{th} = 5.40 eV)	$2s2p\ ^1P - 2p^2\ ^1S$ (E_{th} = 9.94 eV)	$2s2p\ ^1P - 2p^2\ ^3P$ (E_{th} = 4.35 eV)
1.0E+00	1.29E-09		3.91E-10
2.0E+00	1.42E-08	4.58E-10	2.44E-09
4.0E+00	4.15E-08	4.16E-09	4.70E-09
7.0E+00	6.06E-08	8.94E-09	5.02E-09
1.0E+01	6.80E-08	1.23E-08	4.59E-09
2.0E+01	7.26E-08	1.78E-08	3.21E-09
4.0E+01	6.91E-08	2.07E-08	1.89E-09
7.0E+01	6.34E-08	2.09E-08	1.13E-09
1.0E+02	5.92E-08	2.05E-08	7.89E-10
2.0E+02	5.05E-08	1.86E-08	
4.0E+02	4.21E-08	1.63E-08	
7.0E+02	3.58E-08	1.41E-08	
1.0E+03	3.21E-08	1.27E-08	
Accuracy:	20%	20%	20%

References: T.77, T.78, T.79, T.80, T.84, T.85, T.86

Note: The recommended excitation rate data for C^{2+} from the compilation [T.77] were based on close-coupling [T.85, T.86], distorted-wave, and Coulomb-Born-Exchange [T.79, T.80] calculations. This work has been updated to take into account recent 12-term close-coupling calculations [T.84] which have been recommended in compilation [T.78].

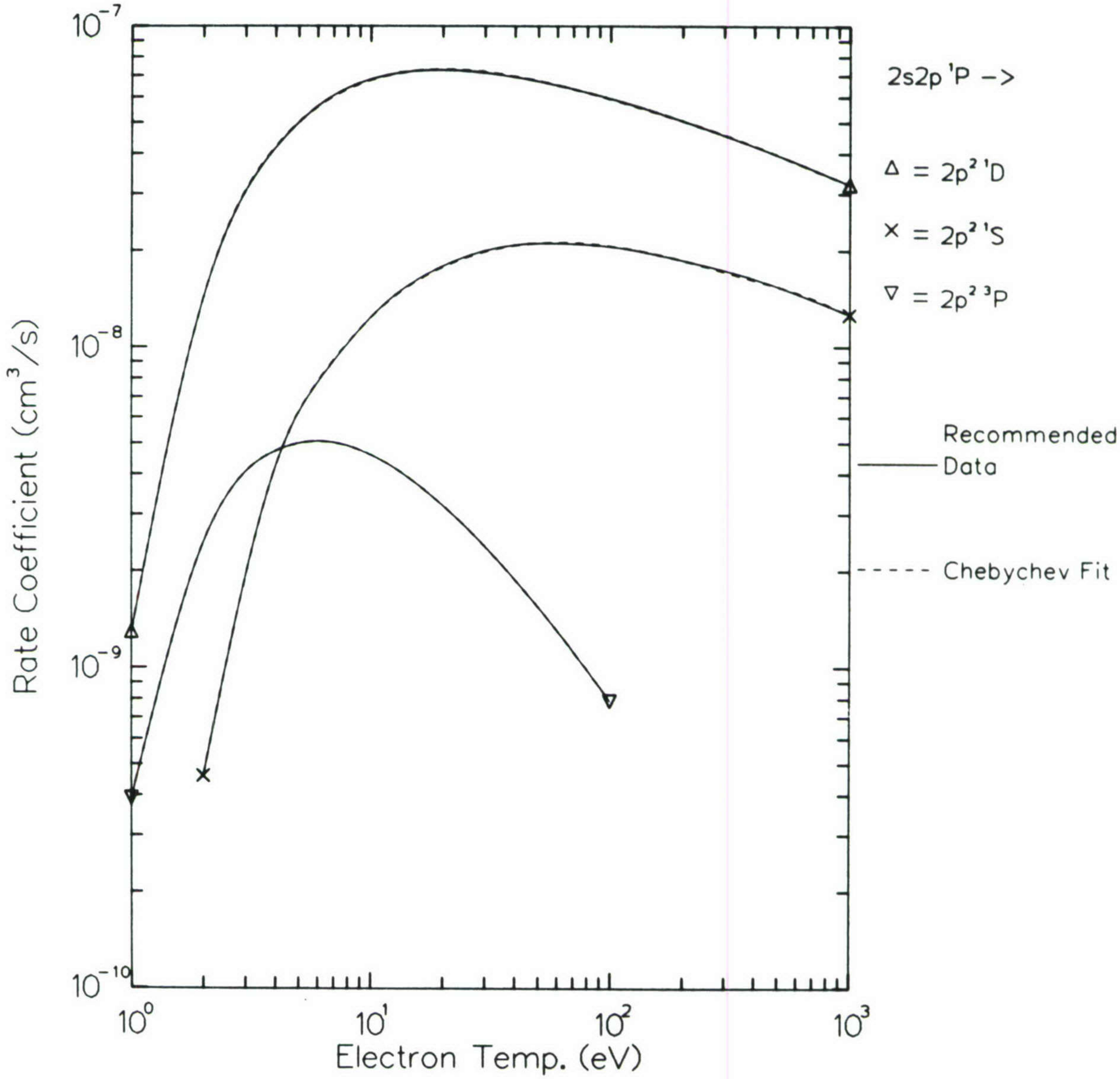
Chebychev Fitting Parameters for Rate Coefficients

E_{min} (eV)	E_{max} (eV)	C1	C2	C3	C4	C5	C6	C7
($2s2p\ ^1P - 2p^2\ ^1D$)								
1.0	1.0E+03	7.91102E-08	1.35541E-08	-2.85916E-08	5.78532E-09	4.46173E-09	-3.93403E-09	1.27224E-09
($2s2p\ ^1P - 2p^2\ ^1S$)								
2.0	1.0E+03	2.47404E-08	6.65702E-09	-7.01802E-09	-1.74301E-10	1.32932E-09	-3.89888E-10	-1.30187E-10
($2s2p\ ^1P - 2p^2\ ^3P$)								
1.0	1.0E+02	4.53753E-09	-1.94691E-10	-2.07678E-09	6.83443E-10	3.24464E-10	-2.89749E-10	7.33497E-11

See appendix for Chebychev fit details.

$e^- + C^{2+}$ (Be-like)

Maxwellian Excitation Rate Coefficients



Electron-Impact Excitation Rate Coefficients for
$e^- + C^{2+}$ (Be-like)

Maxwellian Rate Coefficients (cm^3/s)

e^- Temp. (eV)	$2p^2\ ^3P - 2p^2\ ^1D$ (E_{th} = 1.04 eV)	$2p^2\ ^3P - 2p^2\ ^1S$ (E_{th} = 5.59 eV)	$2p^2\ ^1D - 2p^2\ ^1S$ (E_{th} = 4.54 eV)
1.0E+00	1.06E-08	1.23E-11	6.05E-11
2.0E+00	1.34E-08	1.39E-10	4.19E-10
4.0E+00	1.12E-08	3.79E-10	9.45E-10
7.0E+00	8.80E-09	4.86E-10	1.20E-09
1.0E+01	7.39E-09	4.84E-10	1.25E-09
2.0E+01	5.05E-09	3.81E-10	1.17E-09
4.0E+01	3.50E-09	2.48E-10	9.75E-10
7.0E+01	2.53E-09	1.62E-10	8.03E-10
1.0E+02	2.04E-09	1.20E-10	6.98E-10
Accuracy:	50%	50%	50%

References: T.77, T.78, T.79, T.80, T.84, T.85, T.86

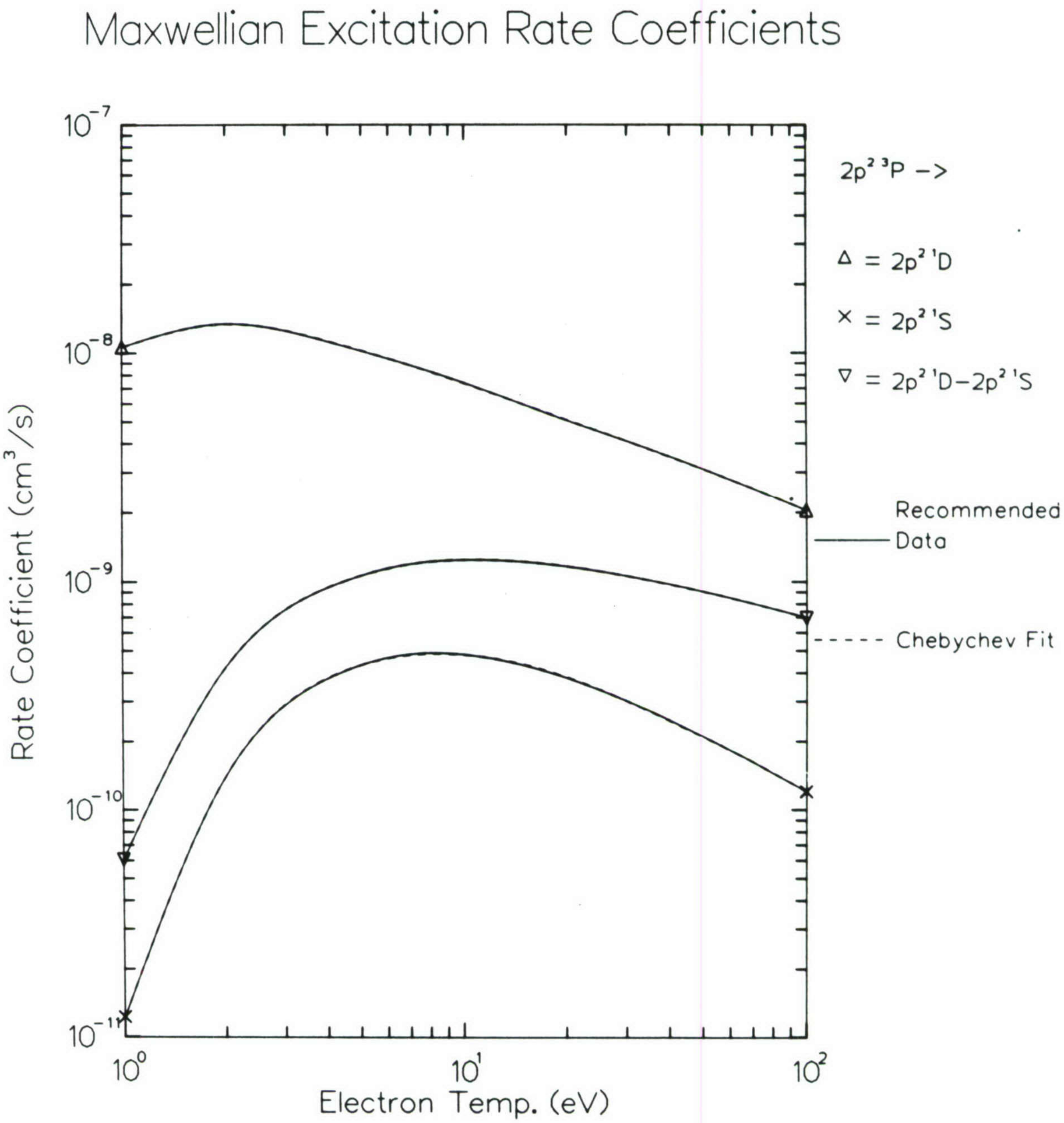
Note: The recommended excitation rate data for C^{2+} from the compilation [T.77] were based on close-coupling [T.85, T.86], distorted-wave, and Coulomb-Born-Exchange [T.79, T.80] calculations. This work has been updated to take into account recent 12-term close-coupling calculations [T.84] which have been recommended in compilation [T.78].

Chebychev Fitting Parameters for Rate Coefficients

E_{min} (eV)	E_{max} (eV)	C1	C2	C3	C4	C5	C6	C7
($2p^2\ ^3P - 2p^2\ ^1D$)								
1.0	1.0E+02	1.50473E-08	-5.79510E-09	-4.85797E-10	1.31937E-09	-6.91067E-10	1.93672E-10	-2.56861E-11
($2p^2\ ^3P - 2p^2\ ^1S$)								
1.0	1.0E+02	4.43393E-10	5.30128E-11	-2.08371E-10	2.35937E-11	5.26805E-11	-2.25310E-11	3.38939E-13
($2p^2\ ^1D - 2p^2\ ^1S$)								
1.0	1.0E+02	1.46516E-09	3.34248E-10	-4.38078E-10	1.98073E-11	8.10894E-11	-3.51639E-11	3.83782E-12

See appendix for Chebychev fit details.

$e^- + C^{2+}$ (Be-like)


Maxwellian Excitation Rate Coefficients
10⁻⁷
10⁻⁸
10⁻⁹
10⁻¹⁰
10⁻¹¹
Rate Coefficient (cm³/s)
10⁰
10¹
10²
Electron Temp. (eV)
2p² ³P ->
Δ = 2p² ¹D
× = 2p² ¹S
∇ = 2p² ¹D−2p² ¹S
Recommended Data
Chebychev Fit

Electron-Impact Excitation Rate Coefficients for $e^- + C^{3+}$ (Li-like)

Maxwellian Rate Coefficients (cm^3/s)

e^- Temp. (eV)	$2s\ ^2S - 2p\ ^2P$ (E_{th} = 8.00 eV)	$2s\ ^2S - 3s\ ^2S$ (E_{th} = 37.6 eV)
1.0E+00	1.21E-10	
2.0E+00	4.77E-09	
4.0E+00	2.57E-08	1.13E-12
7.0E+00	4.79E-08	4.03E-11
1.0E+01	5.85E-08	1.54E-10
2.0E+01	6.79E-08	6.37E-10
4.0E+01	6.63E-08	1.10E-09
7.0E+01	6.11E-08	1.23E-09
1.0E+02	5.70E-08	1.21E-09
2.0E+02	4.85E-08	1.05E-09
4.0E+02	4.03E-08	8.30E-10
7.0E+02	3.43E-08	6.63E-10
1.0E+03	3.07E-08	5.68E-10
2.0E+03	2.45E-08	4.15E-10
4.0E+03	1.94E-08	2.99E-10
7.0E+03	1.59E-08	2.28E-10
1.0E+04	1.40E-08	1.92E-10
2.0E+04	1.08E-08	1.36E-10
Accuracy:	10%	50%

References: E.90, T.77, T.79, T.80, T.87, T.88, T.89

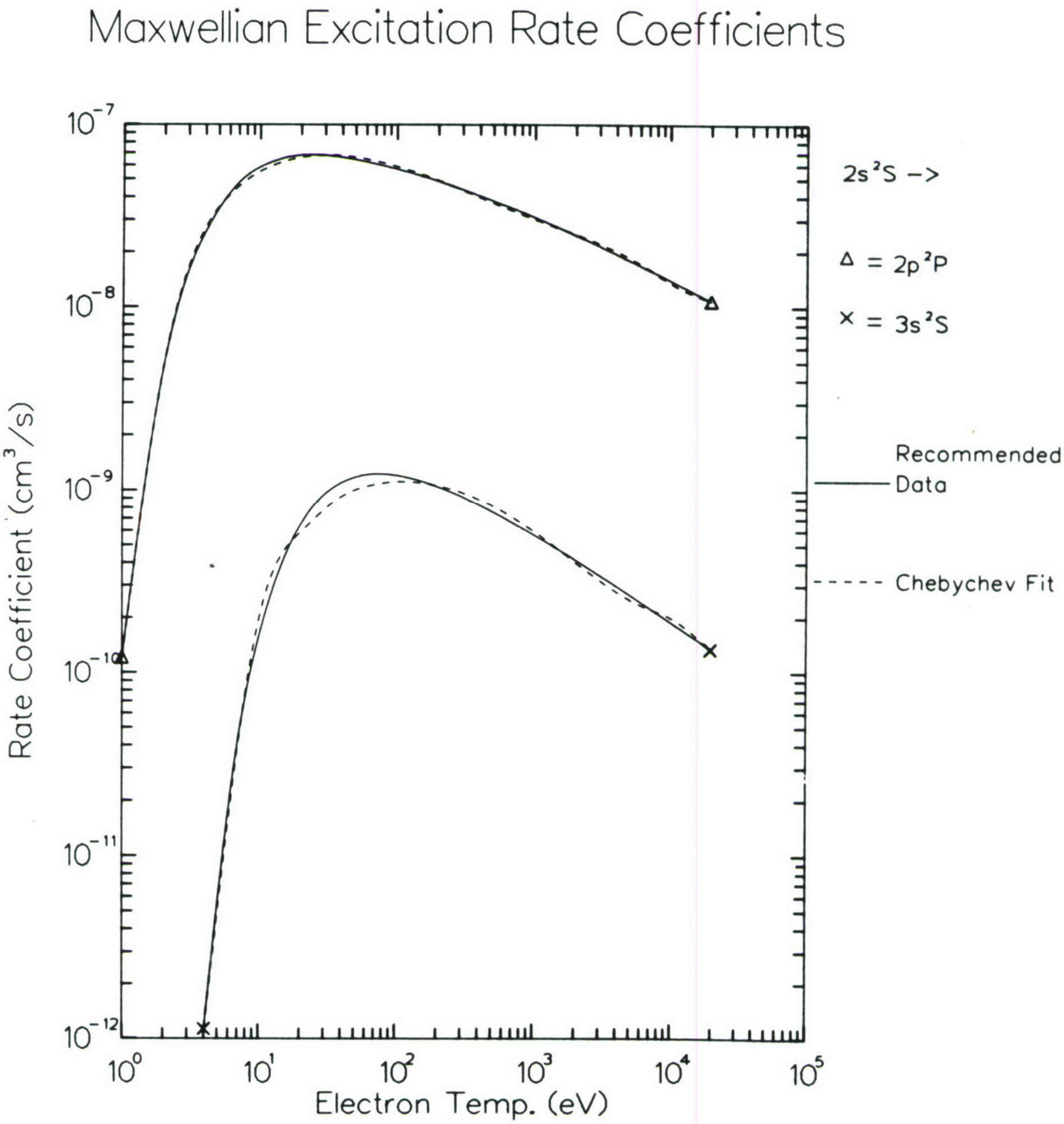
Note: The recommended excitation-rate data for C^{3+} from the compilation [T.77] have been adopted. These were based on close-coupling [T.87, T.88, T.89], distorted-wave, and Coulomb-Born-Exchange [T.79, T.80] calculations. The crossed-beams experimental data [E.90] for 2s-2p excitation are in agreement with the theoretical calculations.

Chebychev Fitting Parameters for Rate Coefficients

E_{min} (eV)	E_{max} (eV)	C1	C2	C3	C4	C5	C6	C7
($2s\ ^2S - 2p\ ^2P$)								
1.0	2.0E+04	5.39551E-08	-1.01306E-09	-2.74640E-08	1.27743E-08	2.81647E-09	-6.39252E-09	3.15965E-09
($2s\ ^2S - 3s\ ^2S$)								
4.0	2.0E+04	8.34016E-10	-1.40723E-11	-4.68671E-10	1.83281E-10	1.09540E-10	-1.02366E-10	1.00959E-11

See appendix for Chebychev fit details.

$e^- + C^{3+}$ (Li-like)



Maxwellian Excitation Rate Coefficients
Rate Coefficient (cm³/s)
10⁻⁷
10⁻⁸
10⁻⁹
10⁻¹⁰
10⁻¹¹
10⁻¹²
10⁰
10¹
10²
10³
10⁴
10⁵
Electron Temp. (eV)
2s²S ->
Δ = 2p²P
× = 3s²S
Recommended Data
Chebychev Fit

Electron-Impact Excitation Rate Coefficients for $e^- + C^{3+}$ (Li-like)

Maxwellian Rate Coefficients (cm^3/s)

e^- Temp. (eV)	2s ^2S - 3p ^2P (E_{th} = 39.7 eV)	2s ^2S - 3d ^2D (E_{th} = 40.3 eV)
7.0E+00	1.59E-11	3.07E-11
1.0E+01	6.99E-11	1.47E-10
2.0E+01	3.48E-10	8.20E-10
4.0E+01	7.11E-10	1.73E-09
7.0E+01	9.53E-10	2.20E-09
1.0E+02	1.08E-09	2.32E-09
2.0E+02	1.26E-09	2.22E-09
4.0E+02	1.36E-09	1.89E-09
7.0E+02	1.37E-09	1.58E-09
1.0E+03	1.35E-09	1.38E-09
2.0E+03	1.25E-09	1.03E-09
4.0E+03	1.11E-09	7.56E-10
7.0E+03	9.81E-10	5.82E-10
1.0E+04	8.98E-10	4.90E-10
2.0E+04	7.43E-10	3.50E-10
Accuracy:	30%	50%

References: E.90, T.77, T.79, T.80, T.87, T.88, T.89

Note: The recommended excitation-rate data for C^{3+} from the compilation [T.77] have been adopted. These were based on close-coupling [T.87, T.88, T.89], distorted-wave, and Coulomb-Born-Exchange [T.79, T.80] calculations. The crossed-beams experimental data [E.90] for 2s-2p excitation are in agreement with the theoretical calculations.

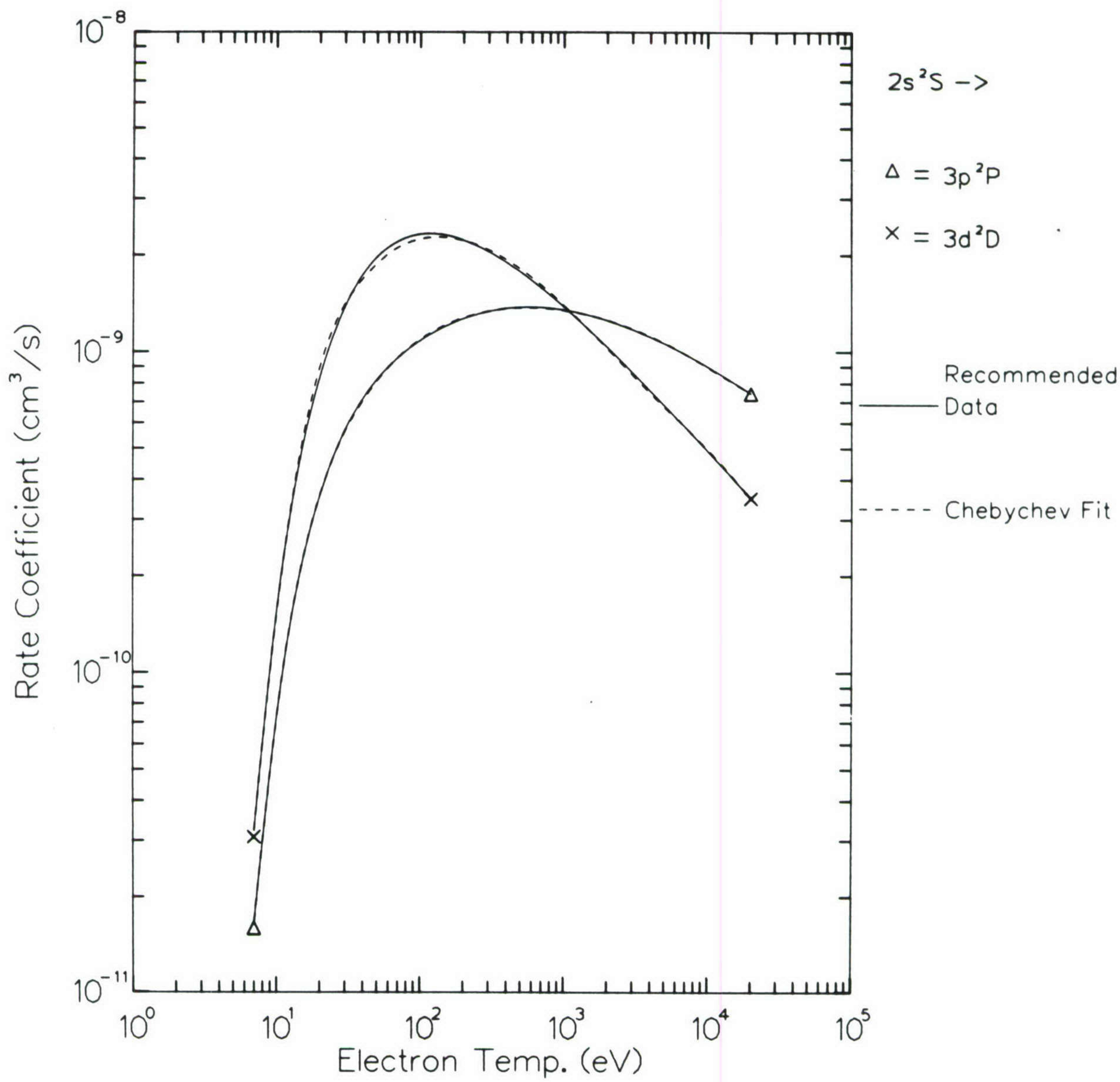
Chebychev Fitting Parameters for Rate Coefficients

E_{min} (eV)	E_{max} (eV)	C1	C2	C3	C4	C5	C6	C7
(2s ^2S - 3p ^2P)								
7.0	2.0E+04	1.57612E-09	3.94890E-10	-4.97202E-10	-4.53910E-12	7.90230E-11	-2.65730E-11	9.80045E-12
(2s ^2S - 3d ^2D)								
7.0	2.0E+04	1.89692E-09	-6.69232E-11	-9.30832E-10	3.90583E-10	1.29744E-10	-1.64349E-10	4.27090E-11

See appendix for Chebychev fit details.

$e^- + C^{3+}$ (Li-like)

Maxwellian Excitation Rate Coefficients



Electron-Impact Excitation Rate Coefficients for
$e^- + C^{4+}$ (He-like)

Maxwellian Rate Coefficients (cm^3/s)

e^- Temp. (eV)	$1s^2\ ^1S - 1s2s\ ^1S$ (E_{th} = 304.4 eV)	$1s^2\ ^1S - 1s2s\ ^3S$ (E_{th} = 299.0 eV)
4.0E+01	8.78E-14	8.29E-14
7.0E+01	1.80E-12	1.29E-12
1.0E+02	5.72E-12	3.07E-12
2.0E+02	2.00E-11	8.39E-12
4.0E+02	3.34E-11	9.11E-12
7.0E+02	3.81E-11	6.99E-12
1.0E+03	3.83E-11	5.42E-12
2.0E+03	3.46E-11	2.85E-12
4.0E+03	2.85E-11	1.30E-12
7.0E+03	2.33E-11	6.44E-13
1.0E+04	2.02E-11	4.02E-13
2.0E+04	1.50E-11	1.55E-13
Accuracy:	20%	20%

References: T.77, T.78, T.80, T.90, T.91, T.92

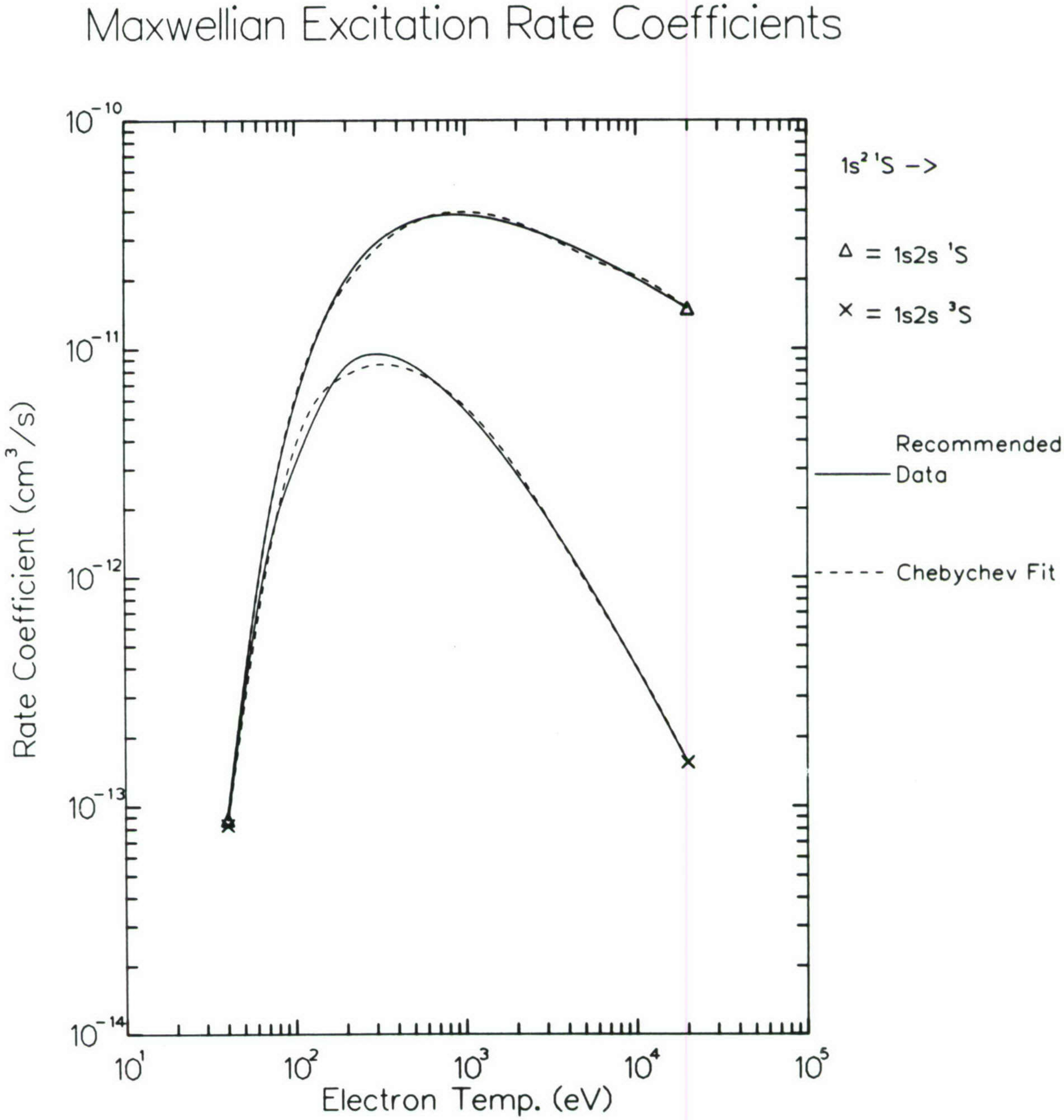
Note: The recommended excitation-rate data for C^{4+} from the compilation [T.77] were based on close-coupling and distorted-wave calculations [T.79, T.80, T.90, T.91]. This work has been updated to take into account an 11-term close-coupling calculation [T.92] which has been recommended in compilation [T.78].

Chebychev Fitting Parameters for Rate Coefficients

E_{min} (eV)	E_{max} (eV)	C1	C2	C3	C4	C5	C6	C7
($1s^2\ ^1S - 1s2s\ ^1S$)								
40.	2.0E+04	3.73521E-11	9.35657E-12	-1.48039E-11	-6.07230E-13	4.81933E-12	-1.33390E-12	-1.18201E-12
($1s^2\ ^1S - 1s2s\ ^3S$)								
40.	2.0E+04	5.17519E-12	-1.07786E-12	-3.31189E-12	2.10691E-12	5.01827E-13	-9.93072E-13	3.41382E-13

See appendix for Chebychev fit details.

$e^- + C^{4+}$ (He-like)



Maxwellian Excitation Rate Coefficients
Rate Coefficient (cm^3/s)
Electron Temp. (eV)
10^{-10}
10^{-11}
10^{-12}
10^{-13}
10^{-14}
10^1
10^2
10^3
10^4
10^5
1s^2 ^{1}S ->
Δ = 1s2s ^{1}S
× = 1s2s ^{3}S
Recommended Data
Chebychev Fit

Electron-Impact Excitation Rate Coefficients for $e^- + C^{4+}$ (He-like)

Maxwellian Rate Coefficients (cm^3/s)

e^- Temp. (eV)	$1s^2\ ^1S - 1s2p\ ^1P$ (E_{th} = 307.9 eV)	$1s^2\ ^1S - 1s2p\ ^3P$ (E_{th} = 304.4 eV)
4.0E+01	2.48E-13	2.13E-13
7.0E+01	5.88E-12	3.92E-12
1.0E+02	2.08E-11	1.13E-11
2.0E+02	9.17E-11	2.99E-11
4.0E+02	1.95E-10	3.36E-11
7.0E+02	2.70E-10	2.57E-11
1.0E+03	3.05E-10	1.95E-11
2.0E+03	3.41E-10	9.67E-12
4.0E+03	3.41E-10	4.19E-12
7.0E+03	3.23E-10	2.00E-12
1.0E+04	3.05E-10	1.23E-12
2.0E+04	2.66E-10	4.61E-13
Accuracy:	10%	20%

References: T.77, T.78, T.80, T.90, T.91, T.92

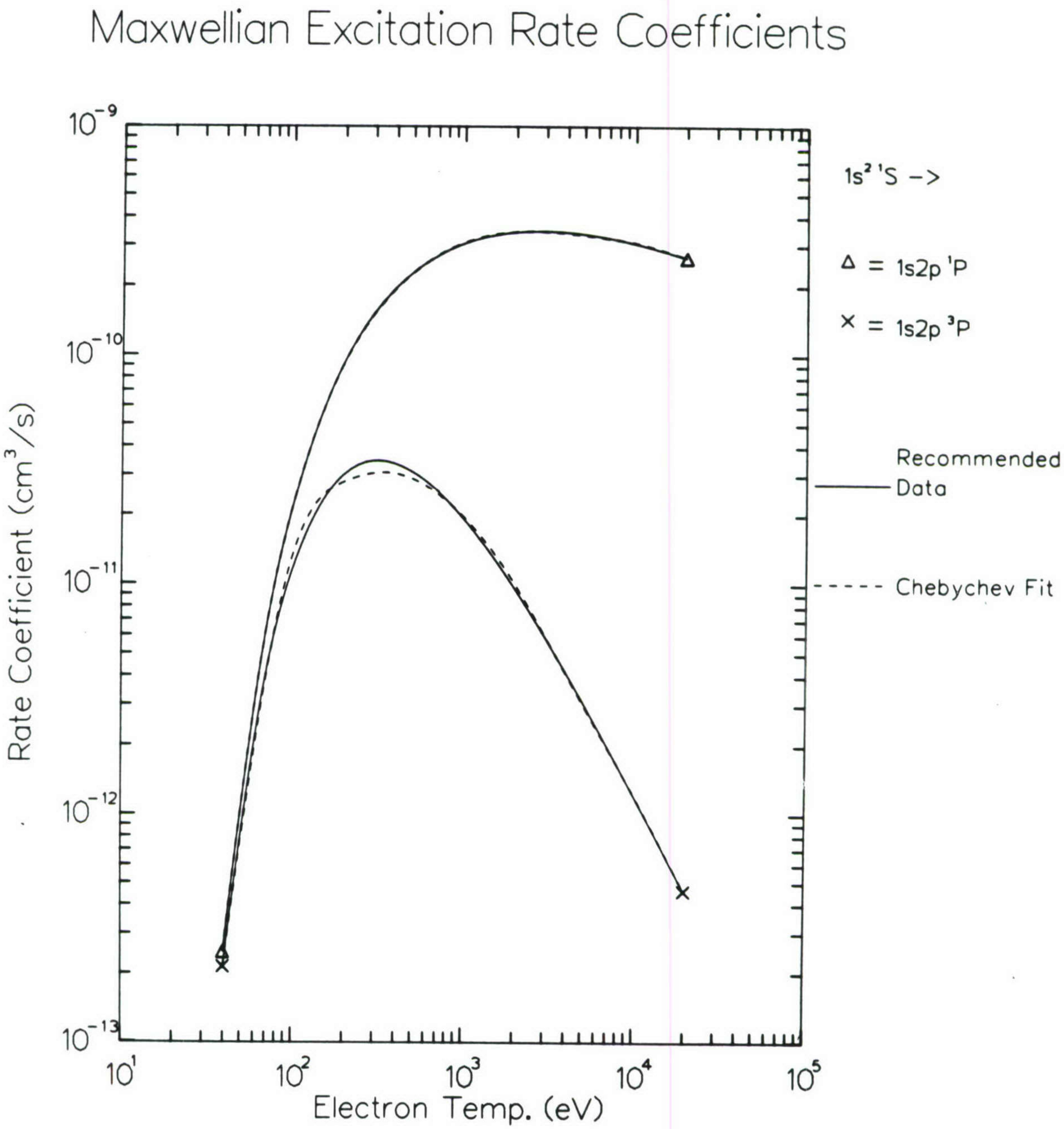
Note: The recommended excitation-rate data for C^{4+} from the compilation [T.77] were based on close-coupling and distorted-wave calculations [T.79, T.80, T.90, T.91]. This work has been updated to take into account an 11-term close-coupling calculation [T.92] which has been recommended in compilation [T.78].

Chebychev Fitting Parameters for Rate Coefficients

E_{min} (eV)	E_{max} (eV)	C1	C2	C3	C4	C5	C6	C7
($1s^2\ ^1S - 1s2p\ ^1P$)								
40.	2.0E+04	3.83412E-10	1.70796E-10	-7.51001E-11	-4.01439E-11	2.34058E-11	1.91827E-12	-7.19387E-12
($1s^2\ ^1S - 1s2p\ ^3P$)								
40.	2.0E+04	1.81218E-11	-3.85824E-12	-1.19129E-11	7.76741E-12	1.85634E-12	-3.78538E-12	1.33304E-12

See appendix for Chebychev fit details.

$e^- + C^{4+}$ (He-like)


Maxwellian Excitation Rate Coefficients
Rate Coefficient (cm³/s)
Electron Temp. (eV)
1s² ¹S ->
Δ = 1s2p ¹P
× = 1s2p ³P
Recommended Data
Chebychev Fit

Electron-Impact Excitation Rate Coefficients for $e^- + C^{4+}$ (He-like)

Maxwellian Rate Coefficients (cm^3/s)

e^- Temp. (eV)	1s2s ^3S - 1s2p ^3P (E_{th} = 5.45 eV)	1s2s ^3S - 1s2s ^1S (E_{th} = 5.43 eV)	1s2s ^3S - 1s2p ^1P (E_{th} = 8.94 eV)
1.0E+00	1.88E-09	4.58E-11	
2.0E+00	2.03E-08	3.83E-10	3.87E-11
4.0E+00	5.59E-08	7.89E-10	2.14E-10
7.0E+00	7.59E-08	8.36E-10	4.54E-10
1.0E+01	8.06E-08	7.57E-10	5.86E-10
2.0E+01	7.69E-08	5.24E-10	6.90E-10
4.0E+01	6.59E-08	3.16E-10	5.24E-10
7.0E+01	5.65E-08	1.97E-10	3.42E-10
1.0E+02	5.09E-08	1.43E-10	2.50E-10
2.0E+02	4.13E-08		1.17E-10
4.0E+02	3.32E-08		4.98E-11
7.0E+02	2.77E-08		2.23E-11
1.0E+03	2.46E-08		1.30E-11
2.0E+03	1.94E-08		
Accuracy:	50%	50%	50%

References: T.77, T.78, T.80, T.90, T.91, T.92

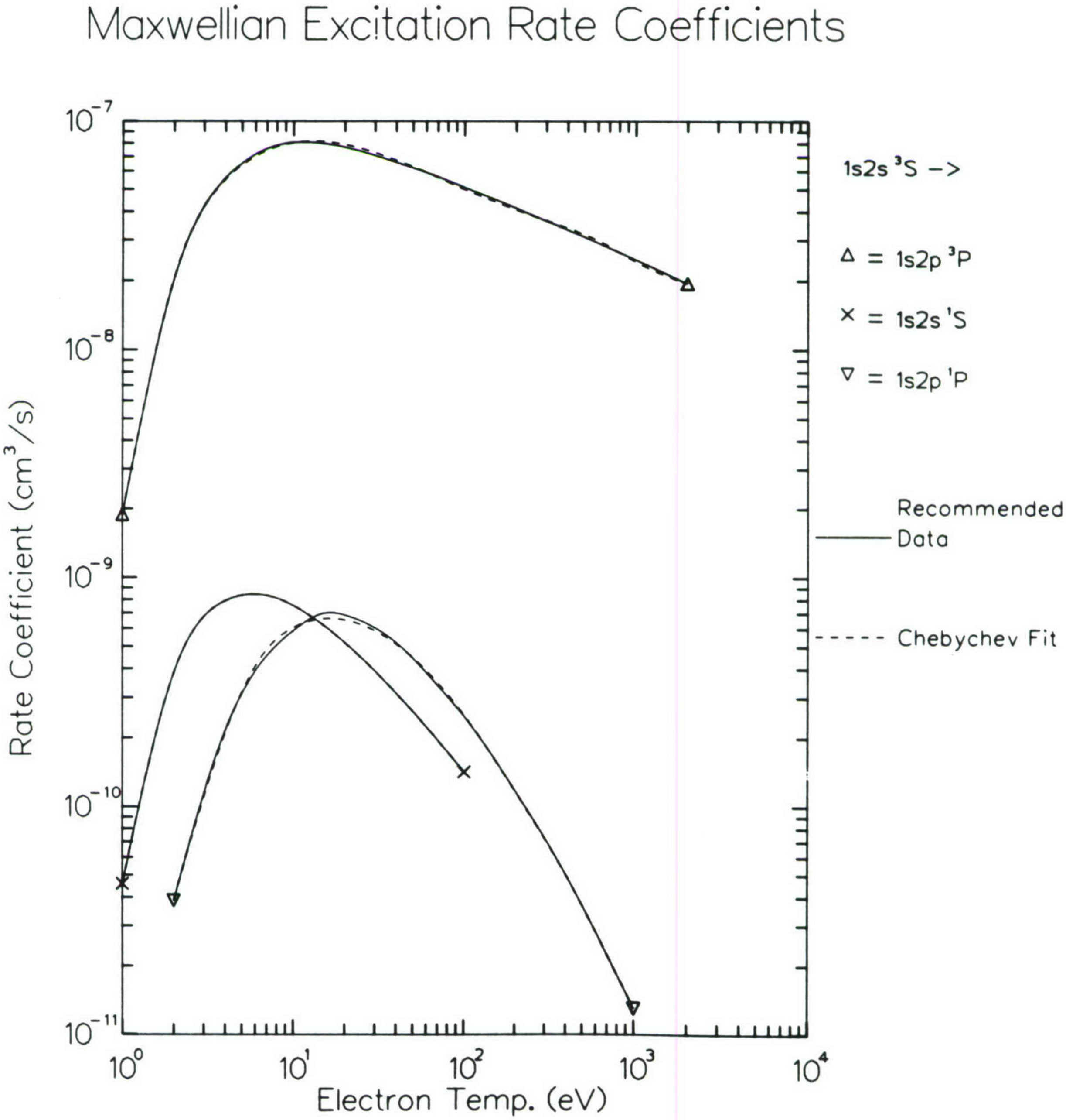
Note: The recommended excitation-rate data for C^{4+} from the compilation [T.77] were based on close-coupling and distorted-wave calculations [T.79, T.80, T.90, T.91]. This work has been updated to take into account an 11-term close-coupling calculation [T.92] which has been recommended in compilation [T.78].

Chebychev Fitting Parameters for Rate Coefficients

E_{min} (eV)	E_{max} (eV)	C1	C2	C3	C4	C5	C6	C7
(1s2s ^3S - 1s2p ^3P)								
1.0	2.0E+03	7.32674E-08	-2.77845E-10	-3.07529E-08	1.52036E-08	1.21696E-09	-6.13424E-09	3.57506E-09
(1s2s ^3S - 1s2s ^1S)								
1.0	1.0E+02	7.41253E-10	-1.41478E-11	-3.49289E-10	1.20041E-10	5.60562E-11	-5.73305E-11	1.69340E-11
(1s2s ^3S - 1s2p ^1P)								
2.0	1.0E+03	4.39928E-10	-1.02205E-10	-2.50990E-10	1.56271E-10	3.52560E-11	-6.69336E-11	2.16313E-11

See appendix for Chebychev fit details.

$e^- + C^{4+}$ (He-like)


Maxwellian Excitation Rate Coefficients
Rate Coefficient (cm³/s)
10⁻⁷
10⁻⁸
10⁻⁹
10⁻¹⁰
10⁻¹¹
10⁰
10¹
10²
10³
10⁴
Electron Temp. (eV)
1s2s ³S ->
Δ = 1s2p ³P
× = 1s2s ¹S
∇ = 1s2p ¹P
Recommended Data
Chebychev Fit

Electron-Impact Excitation Rate Coefficients for
$e^- + C^{4+}$ (He-like)

Maxwellian Rate Coefficients (cm^3/s)

e^- Temp. (eV)	$1s2s\ ^1S - 1s2p\ ^1P$ (E_{th} = 3.51 eV)	$1s2p\ ^3P - 1s2p\ ^1P$ (E_{th} = 3.49 eV)
1.0E+00	1.17E-08	2.02E-10
2.0E+00	4.81E-08	8.10E-10
4.0E+00	8.35E-08	1.35E-09
7.0E+00	9.49E-08	1.46E-09
1.0E+01	9.50E-08	1.39E-09
2.0E+01	8.65E-08	1.10E-09
4.0E+01	7.40E-08	7.43E-10
7.0E+01	6.37E-08	4.92E-10
1.0E+02	5.76E-08	3.63E-10
2.0E+02	4.67E-08	1.85E-10
4.0E+02	3.75E-08	8.54E-11
7.0E+02	3.11E-08	4.26E-11
1.0E+03	2.75E-08	2.66E-11
2.0E+03	2.16E-08	
Accuracy:	50%	50%

References: T.77, T.78, T.80, T.90, T.91, T.92

Note: The recommended excitation-rate data for C^{4+} from the compilation [T.77] were based on close-coupling and distorted-wave calculations [T.79, T.80, T.90, T.91]. This work has been updated to take into account an 11-term close-coupling calculation [T.92] which has been recommended in compilation [T.78].

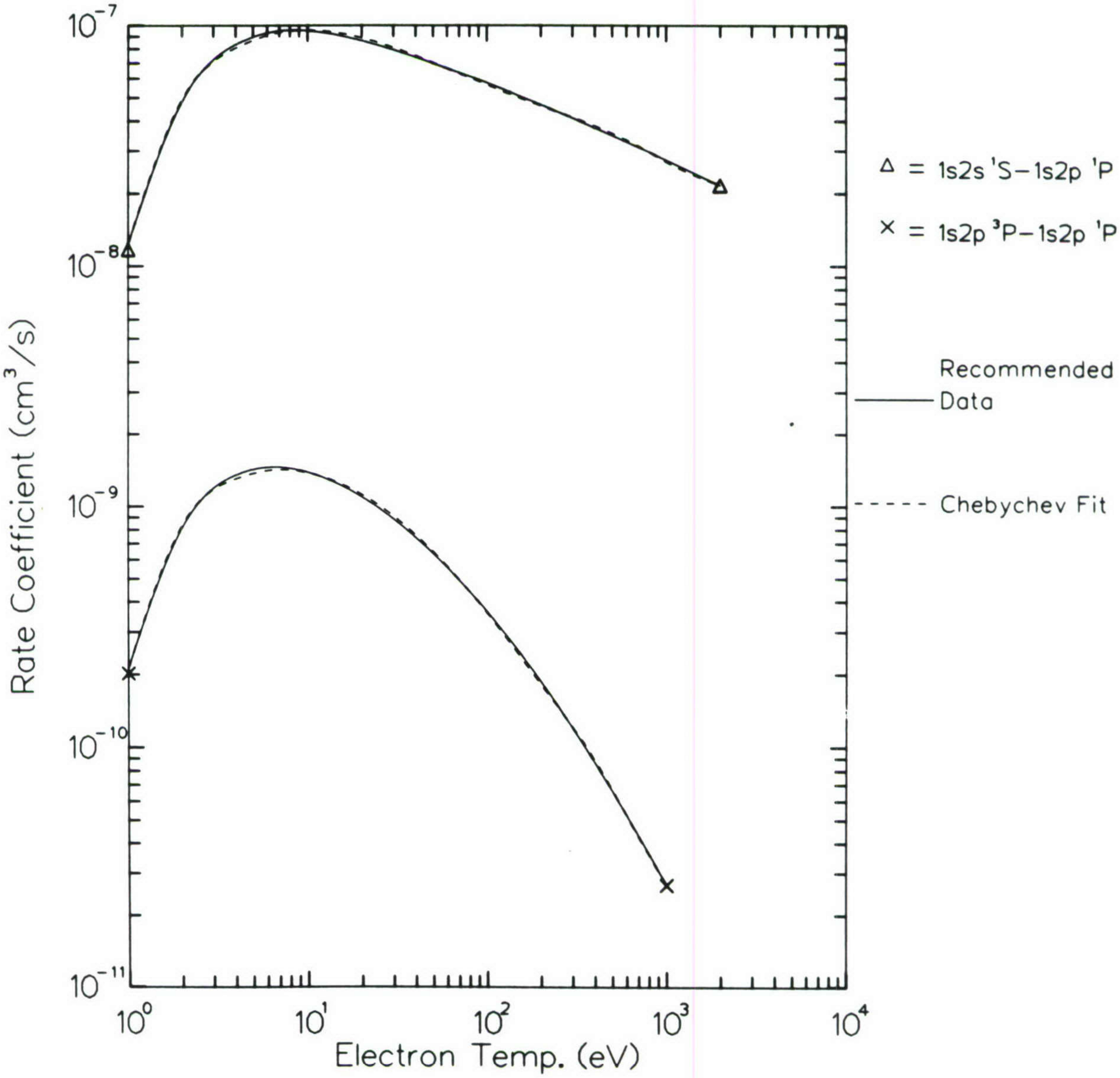
Chebychev Fitting Parameters for Rate Coefficients

E_{min} (eV)	E_{max} (eV)	C1	C2	C3	C4	C5	C6	C7
($1s2s\ ^1S - 1s2p\ ^1P$)								
1.0	2.0E+03	9.57597E-08	-1.08946E-08	-3.04412E-08	1.88434E-08	-3.28294E-09	-2.97921E-09	2.48029E-09
($1s2p\ ^3P - 1s2p\ ^1P$)								
1.0	1.0E+03	1.09238E-09	-3.93695E-10	-4.14713E-10	3.72222E-10	-4.61772E-11	-6.58266E-11	2.86985E-11

See appendix for Chebychev fit details.

$e^- + C^{4+}$ (He-like)

Maxwellian Excitation Rate Coefficients



Electron-Impact Excitation Rate Coefficients for
$e^- + C^{5+}$ (H-like)

Maxwellian Rate Coefficients (cm^3/s)

e^- Temp. (eV)	1s-2p (E_{th} = 367.5 eV)	1s-2s (E_{th} = 367.5 eV)
4.0E+01	4.85E-14	1.31E-14
7.0E+01	1.97E-12	4.86E-13
1.0E+02	8.34E-12	1.91E-12
2.0E+02	4.26E-11	8.14E-12
4.0E+02	9.33E-11	1.44E-11
7.0E+02	1.29E-10	1.66E-11
1.0E+03	1.45E-10	1.69E-11
2.0E+03	1.61E-10	1.55E-11
4.0E+03	1.61E-10	1.30E-11
7.0E+03	1.53E-10	1.08E-11
1.0E+04	1.45E-10	9.42E-12
2.0E+04	1.26E-10	7.07E-12
Accuracy:	10%	10%

References: T.77, T.79, T.80, T.93

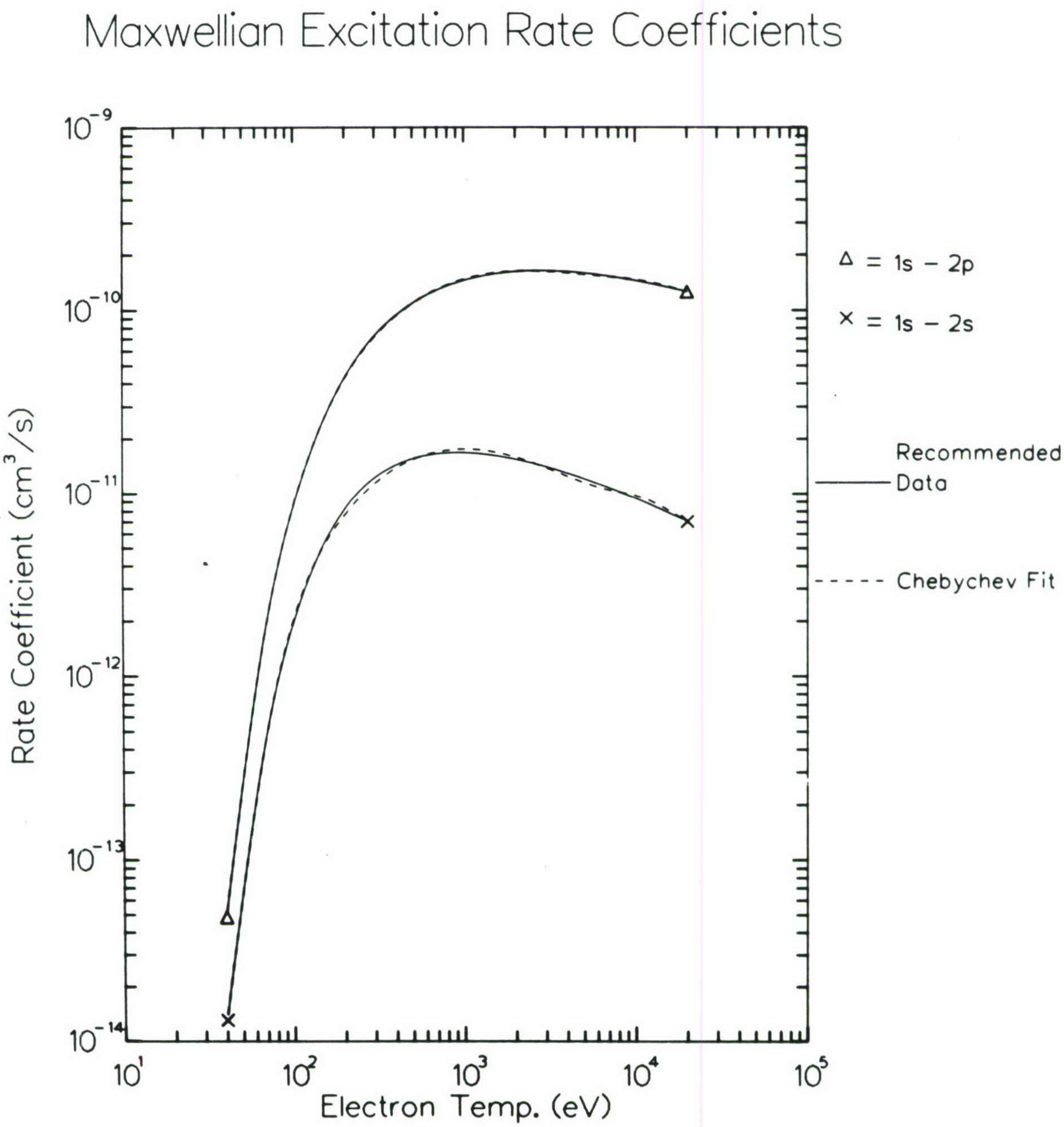
Note: The recommended excitation-rate data for C^{5+} are from the compilation [T.77]. For transitions to n=2, these are based on close-coupling and Coulomb-Born-Exchange calculations [T.93], and solely on Coulomb-Born Exchange calculations [T.79, T.80] for transitions to n = 3.

Chebychev Fitting Parameters for Rate Coefficients

E_{min} (eV)	E_{max} (eV)	C1	C2	C3	C4	C5	C6	C7
(1s-2p)								
40.	2.0E+04	1.81409E-10	8.13984E-11	-3.54275E-11	-1.89610E-11	1.17905E-11	3.78934E-13	-4.20250E-12
(1s-2s)								
40.	2.0E+04	1.65836E-11	4.64927E-12	-6.31928E-12	-5.68996E-13	2.23867E-12	-5.68786E-13	-6.86651E-13

See appendix for Chebychev fit details.

$e^- + C^{5+}$ (H-like)


Maxwellian Excitation Rate Coefficients
Rate Coefficient (cm³/s)
Electron Temp. (eV)
10⁻⁹
10⁻¹⁰
10⁻¹¹
10⁻¹²
10⁻¹³
10⁻¹⁴
10¹
10²
10³
10⁴
10⁵
Δ = 1s – 2p
× = 1s – 2s
Recommended Data
Chebychev Fit

Electron-Impact Excitation Rate Coefficients for $e^- + C^{5+}$ (H-like)

Maxwellian Rate Coefficients (cm^3/s)

e^- Temp. (eV)	1s-3p (E_{th} = 435.5 eV)	1s-3s (E_{th} = 435.5 eV)	1s-3d (E_{th} = 435.6 eV)
4.0E+01	1.99E-15	4.54E-16	3.54E-16
7.0E+01	1.63E-13	3.69E-14	2.67E-14
1.0E+02	9.03E-13	2.01E-13	1.38E-13
2.0E+02	6.14E-12	1.28E-12	7.89E-13
4.0E+02	1.50E-11	2.76E-12	1.59E-12
7.0E+02	2.13E-11	3.40E-12	1.95E-12
1.0E+03	2.42E-11	3.49E-12	2.04E-12
2.0E+03	2.72E-11	3.16E-12	1.97E-12
4.0E+03	2.72E-11	2.56E-12	1.71E-12
7.0E+03	2.58E-11	2.07E-12	1.45E-12
1.0E+04	2.44E-11	1.78E-12	1.28E-12
2.0E+04	2.13E-11	1.31E-12	9.79E-13
Accuracy:	15%	30%	30%

References: T.77, T.79, T.80, T.93

Note: The recommended excitation-rate data for C^{5+} are from the compilation [T.77]. For transitions to n=2, these are based on close-coupling and Coulomb-Born-Exchange calculations [T.93], and solely on Coulomb-Born Exchange calculations [T.79, T.80] for transitions to n = 3.

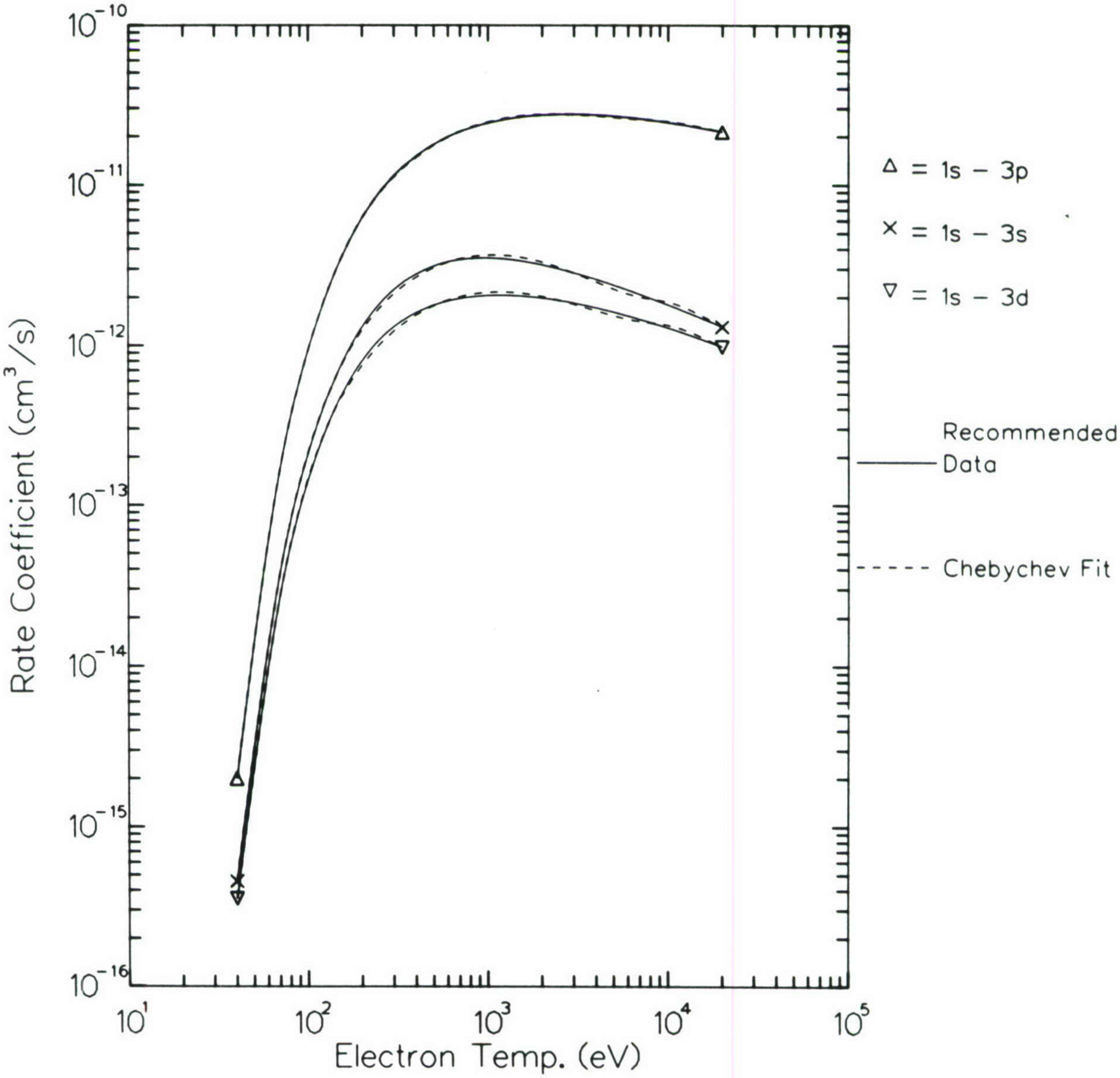
Chebychev Fitting Parameters for Rate Coefficients

E_{min} (eV)	E_{max} (eV)	C1	C2	C3	C4	C5	C6	C7
(1s-3p)								
40.	2.0E+04	3.02036E-11	1.39385E-11	-5.71101E-12	-3.52584E-12	2.03280E-12	2.27822E-13	-7.81128E-13
(1s-3s)								
40.	2.0E+04	3.19307E-12	9.35650E-13	-1.27361E-12	-2.13443E-13	5.33256E-13	-7.08290E-14	-2.04350E-13
(1s-3d)								
40.	2.0E+04	2.05467E-12	6.80268E-13	-7.08131E-13	-1.49368E-13	2.70774E-13	-4.44809E-14	-1.03205E-13

See appendix for Chebychev fit details.

$e^- + C^{5+}$ (H-like)

Maxwellian Excitation Rate Coefficients



Electron-Impact Excitation Rate Coefficients for $e^- + O^+$ (N-like)

Maxwellian Rate Coefficients (cm^3/s)

e^- Temp. (eV)	$2s^22p^3\ ^4S - 2s^22p^3\ ^2D$ (E_{th} = 3.32 eV)	$2s^22p^3\ ^4S - 2s^22p^3\ ^2P$ (E_{th} = 5.02 eV)	$2s^22p^3\ ^2D - 2s^22p^3\ ^2P$ (E_{th} = 1.69 eV)
1.0E+00	8.70E-10	6.62E-11	2.86E-09
2.0E+00	3.54E-09	6.01E-10	4.93E-09
4.0E+00	6.21E-09	1.60E-09	5.70E-09
7.0E+00	7.12E-09	2.24E-09	5.50E-09
1.0E+01	7.13E-09	2.48E-09	5.15E-09
2.0E+01	6.38E-09	2.59E-09	4.26E-09
4.0E+01	5.19E-09	2.44E-09	3.33E-09
7.0E+01	4.22E-09	2.22E-09	2.65E-09
1.0E+02	3.65E-09	2.06E-09	2.27E-09
Accuracy:	50%	50%	50%

References: T.77, T.94, T.95, T.96, T.97

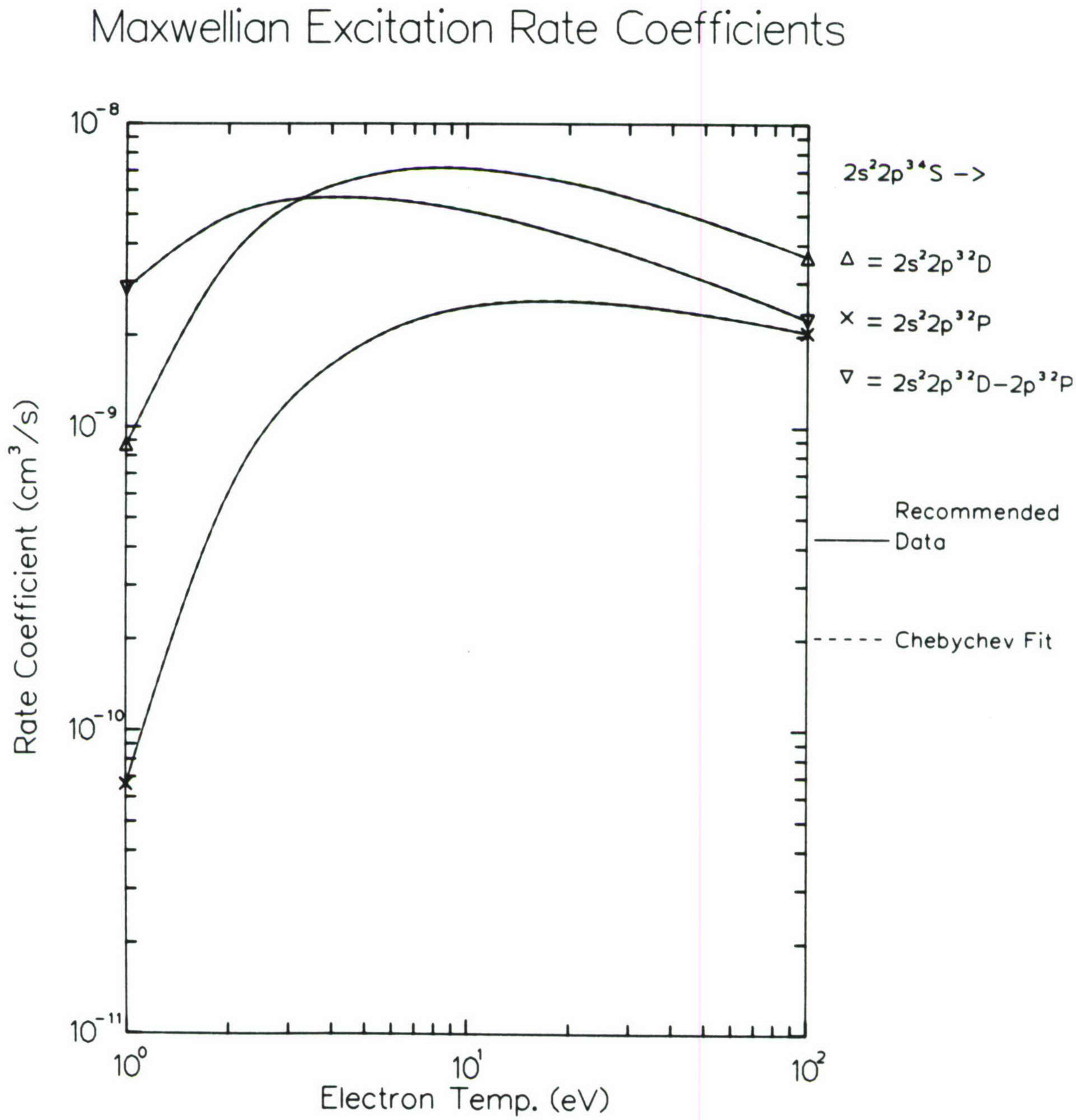
Notes: The recommended excitation-rate data for O^+ from the compilation [T.77] were based on close-coupling [T.94, T.95, T.96] calculations. This work has been updated to take into account a recent 8-term close-coupling calculation [T.97].

Chebychev Fitting Parameters for Rate Coefficients

E_{min} (eV)	E_{max} (eV)	C1	C2	C3	C4	C5	C6	C7
($2s^22p^3\ ^4S - 2s^22p^3\ ^2D$)								
1.0	1.0E+02	8.80798E-09	1.15790E-09	-2.48186E-09	4.14217E-10	2.93441E-10	-1.84733E-10	4.23228E-11
($2s^22p^3\ ^4S - 2s^22p^3\ ^2P$)								
1.0	1.0E+02	3.22815E-09	1.12207E-09	-7.04674E-10	-8.07520E-11	1.55186E-10	-4.61581E-11	-3.24439E-12
($2s^22p^3\ ^2D - 2s^22p^3\ ^2P$)								
1.0	1.0E+02	7.81968E-09	-8.07074E-10	-1.31148E-09	5.51083E-10	-5.05982E-11	-3.56645E-11	1.63166E-11

See appendix for Chebychev fit details.

$e^- + O^+$ (N-like)


Maxwellian Excitation Rate Coefficients
10^{-8}
10^{-9}
10^{-10}
10^{-11}
Rate Coefficient (cm^3/s)
10^0
10^1
10^2
Electron Temp. (eV)
$2s^2 2p^3\,^4S$ ->
Δ = $2s^2 2p^3\,^2D$
$\times$ = $2s^2 2p^3\,^2P$
∇ = $2s^2 2p^3\,^2D - 2p^3\,^2P$
Recommended Data
Chebychev Fit

Electron-Impact Excitation Rate Coefficients for
$e^- + O^+$ (N-like)

Maxwellian Rate Coefficients (cm^3/s)

e^- Temp. (eV)	$2s^22p^3\ ^4S - 2s2p^4\ ^4P$ (E_{th} = 14.9 eV)	$2s^22p^3\ ^4S - 2s^22p^23s\ ^4P$ (E_{th} = 23.0 eV)
2.0E+00	2.75E-11	
4.0E+00	9.19E-10	1.41E-11
7.0E+00	3.93E-09	1.29E-10
1.0E+01	6.85E-09	2.97E-10
2.0E+01	1.24E-08	7.30E-10
4.0E+01	1.54E-08	1.11E-09
7.0E+01	1.57E-08	1.37E-09
1.0E+02	1.52E-08	1.51E-09
2.0E+02	1.33E-08	1.74E-09
4.0E+02	1.11E-08	1.85E-09
7.0E+02	9.31E-09	1.85E-09
1.0E+03	8.26E-09	1.81E-09
2.0E+03	6.47E-09	1.67E-09
4.0E+03	5.00E-09	1.48E-09
7.0E+03	4.03E-09	1.30E-09
1.0E+04	3.51E-09	1.19E-09
2.0E+04	2.66E-09	9.81E-10
Accuracy:	50%	50%

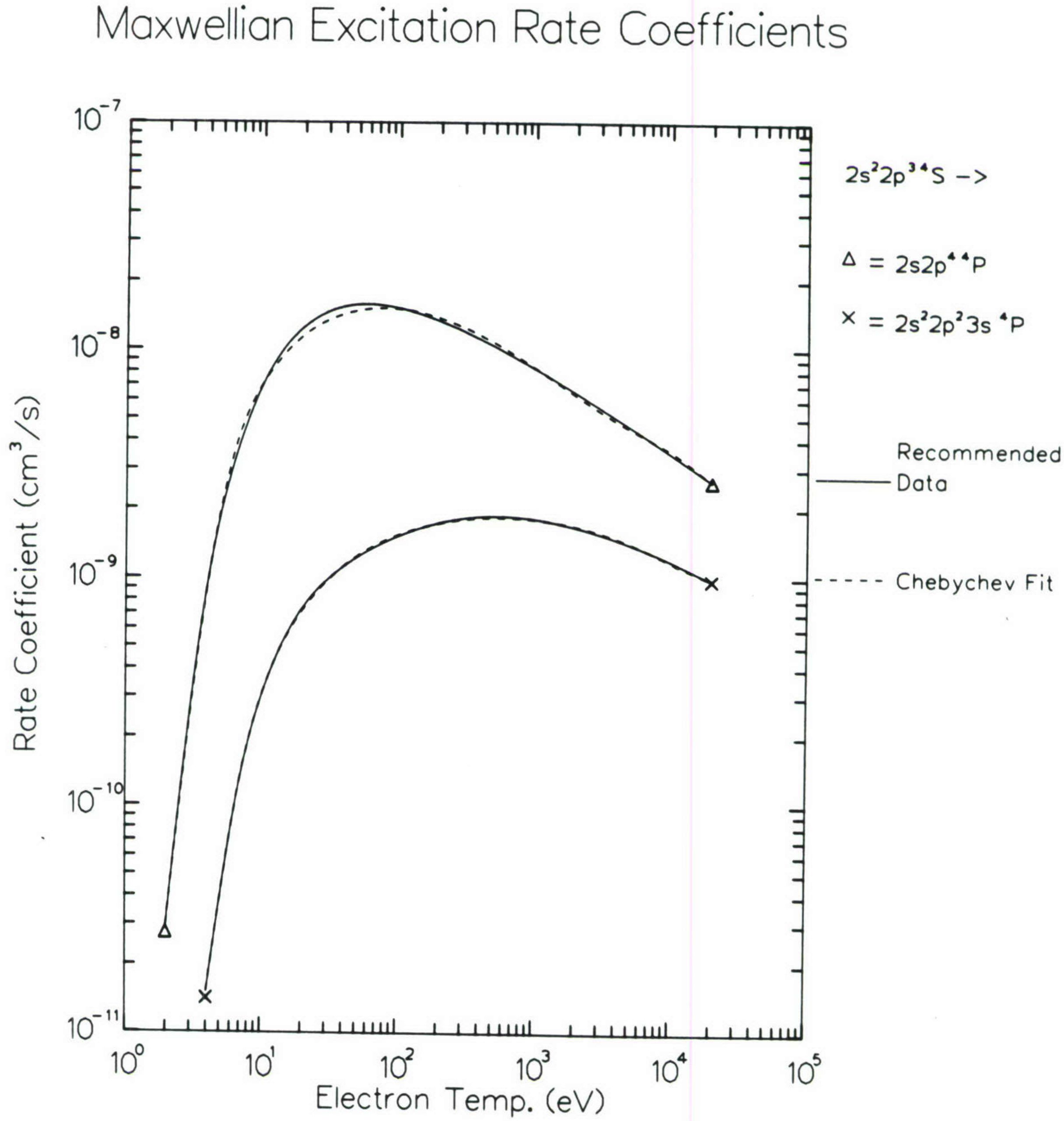
References: T.77, T.94, T.95, T.96, T.97

Notes: The recommended excitation-rate data for O^+ from the compilation [T.77] were based on close-coupling [T.94, T.95, T.96] calculations. This work has been updated to take into account a recent 8-term close-coupling calculation [T.97].

Chebychev Fitting Parameters for Rate Coefficients

E_{min} (eV)	E_{max} (eV)	C1	C2	C3	C4	C5	C6	C7
($2s^22p^3\ ^4S - 2s2p^4\ ^4P$)								
2.0	2.0E+04	1.22744E-08	4.37814E-10	-6.40274E-09	2.13839E-09	1.38860E-09	-1.26697E-09	2.13682E-10
($2s^22p^3\ ^4S - 2s^22p^23s\ ^4P$)								
4.0	2.0E+04	2.07544E-09	5.54215E-10	-6.64059E-10	-4.59300E-11	1.07165E-10	-2.32950E-11	1.82916E-11

$e^- + O^+$ (N-like)



Maxwellian Excitation Rate Coefficients
Rate Coefficient (cm^3/s)
Electron Temp. (eV)
10^{-7}
10^{-8}
10^{-9}
10^{-10}
10^{-11}
10^0
10^1
10^2
10^3
10^4
10^5
$2s^22p^3\,{}^4S$ ->
Δ = $2s2p^4\,{}^4P$
× = $2s^22p^23s\,{}^4P$
Recommended Data
Chebychev Fit

Electron-Impact Excitation Rate Coefficients for $e^- + O^{2+}$ (C-like)

Maxwellian Rate Coefficients (cm^3/s)

e^- Temp. (eV)	$2s^22p^2\ ^3P - 2s^22p^2\ ^1D$ (E_{th} = 2.49 eV)	$2s^22p^2\ ^3P - 2s^22p^2\ ^1S$ (E_{th} = 5.33 eV)
1.0E+00	1.66E-09	1.24E-11
2.0E+00	4.38E-09	1.40E-10
4.0E+00	6.18E-09	4.02E-10
7.0E+00	6.19E-09	5.40E-10
1.0E+01	5.63E-09	5.54E-10
2.0E+01	3.97E-09	4.53E-10
4.0E+01	2.36E-09	2.93E-10
7.0E+01	1.42E-09	1.81E-10
1.0E+02	9.91E-10	1.27E-10
2.0E+02	4.65E-10	
Accuracy:	20%	20%

References: T.77, T.78, T.79, T.80, T.98, T.99, T.100, T.101, T.102, T.103

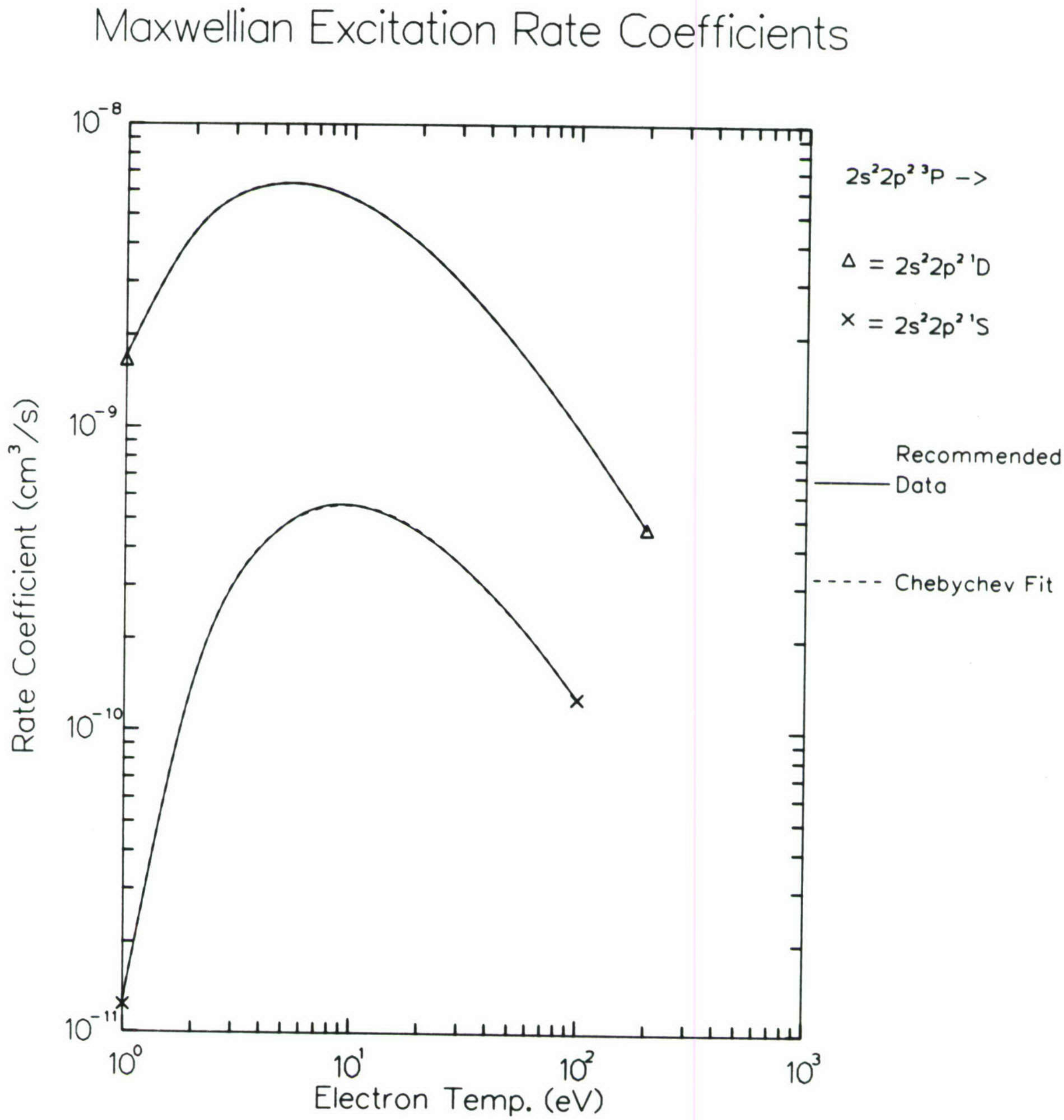
Notes: The recommended excitation-rate data for O^{2+} from the compilation [T.77] were based on close-coupling [T.98, T.99, T.100] and distorted-wave [T.79, T.80, T.102] calculations. This work has been updated in compilation [T.103] to take into account recent 12-term level-to-level close-coupling calculations [T.101] which have also been recommended in compilation [T.78].

Chebychev Fitting Parameters for Rate Coefficients

E_{min} (eV)	E_{max} (eV)	C1	C2	C3	C4	C5	C6	C7
($2s^22p^2\ ^3P - 2s^22p^2\ ^1D$)								
1.0	**2.0E+02**	**5.83959E-09**	**-1.57376E-09**	**-1.97696E-09**	**1.22697E-09**	**3.54901E-11**	**-2.49207E-10**	**8.30108E-11**
($2s^22p^2\ ^3P - 2s^22p^2\ ^1S$)								
1.0	**1.0E+02**	**4.96925E-10**	**6.60381E-11**	**-2.38159E-10**	**1.00214E-11**	**6.25409E-11**	**-1.85375E-11**	**-2.96558E-12**

See appendix for Chebychev fit details.

$e^- + O^{2+}$ (C-like)


Maxwellian Excitation Rate Coefficients
10^{-8}
10^{-9}
10^{-10}
10^{-11}
Rate Coefficient (cm^3/s)
10^0
10^1
10^2
10^3
Electron Temp. (eV)
$2s^22p^2\,{}^3P$ ->
Δ = $2s^22p^2\,{}^1D$
× = $2s^22p^2\,{}^1S$
Recommended Data
Chebychev Fit

Electron-Impact Excitation Rate Coefficients for
$e^- + O^{2+}$ (C-like)

Maxwellian Rate Coefficients (cm^3/s)

e^- Temp. (eV)	$2s^22p^2\ ^3P - 2s2p^3\ ^5S$ (E_{th} = 7.45 eV)	$2s^22p^2\ ^3P - 2s2p^3\ ^1P$ (E_{th} = 26.1 eV)
1.0E+00	6.63E-12	
2.0E+00	2.06E-10	
4.0E+00	8.67E-10	1.05E-12
7.0E+00	1.28E-09	1.25E-11
1.0E+01	1.35E-09	3.09E-11
2.0E+01	1.12E-09	7.14E-11
4.0E+01	7.35E-10	7.86E-11
7.0E+01	4.65E-10	6.16E-11
1.0E+02	3.33E-10	4.75E-11
2.0E+02		2.39E-11
Accuracy:	50%	50%

References: T.77, T.78, T.79, T.80, T.98, T.99, T.100, T.101, T.102, T.103

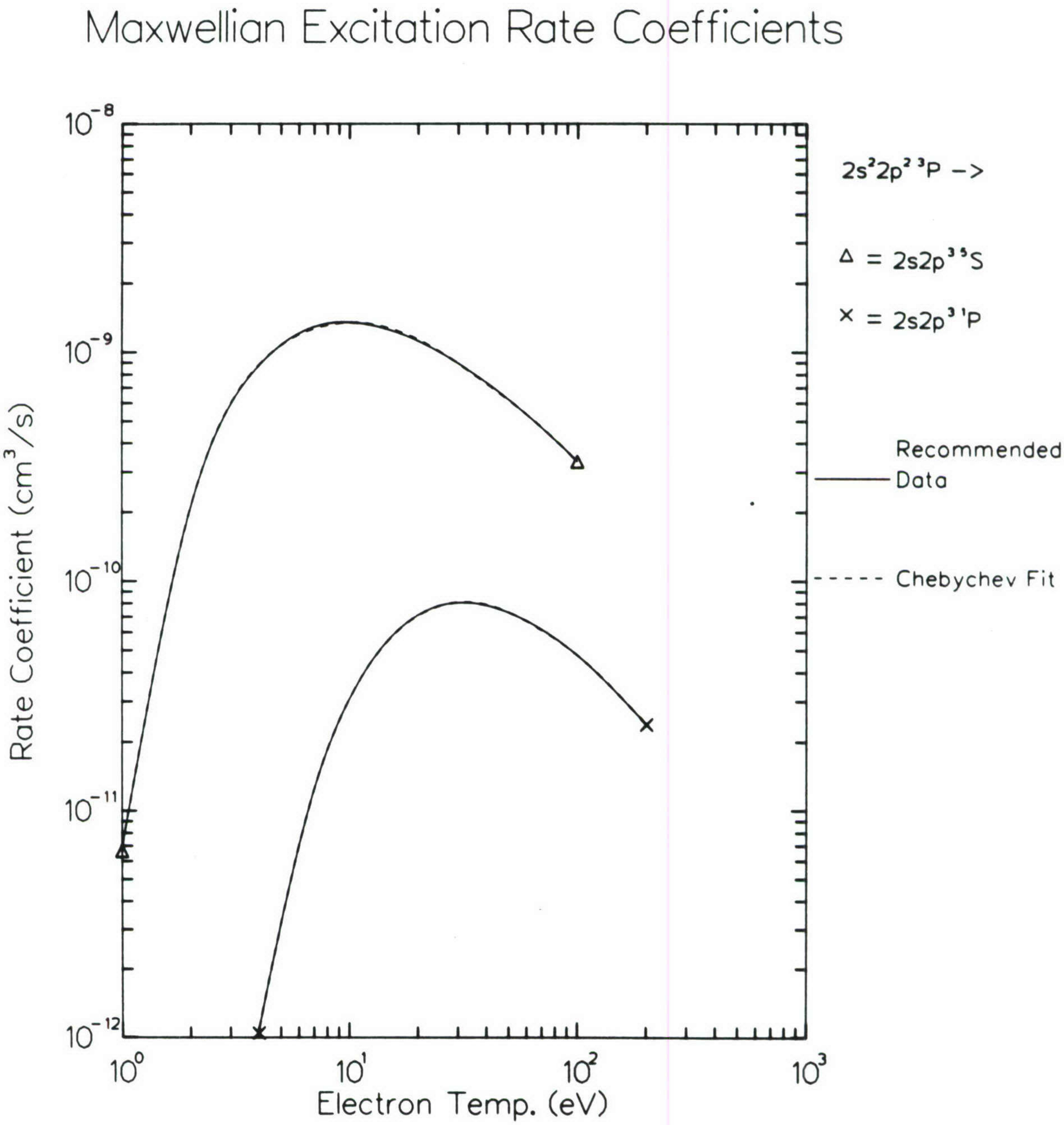
Notes: The recommended excitation-rate data for O^{2+} from the compilation [T.77] were based on close-coupling [T.98, T.99, T.100] and distorted-wave [T.79, T.80, T.102] calculations. This work has been updated in compilation [T.103] to take into account recent 12-term level-to-level close-coupling calculations [T.101] which have also been recommended in compilation [T.78].

Chebychev Fitting Parameters for Rate Coefficients

E_{min} (eV)	E_{max} (eV)	C1	C2	C3	C4	C5	C6	C7
($2s^22p^2\ ^3P - 2s2p^3\ ^5S$)								
1.0	1.0E+03	1.15079E-09	2.26517E-10	-5.71564E-10	-1.82049E-11	1.80139E-10	-4.54254E-11	-1.44553E-11
($2s^22p^2\ ^3P - 2s2p^3\ ^1P$)								
4.0	2.0E+02	7.48461E-11	1.65486E-11	-3.17976E-11	-4.05872E-12	9.05154E-12	-1.07686E-12	-2.21889E-12

See appendix for Chebychev fit details.

$e^- + O^{2+}$ (C-like)



Maxwellian Excitation Rate Coefficients
Rate Coefficient (cm³/s)
Electron Temp. (eV)
10⁻⁸
10⁻⁹
10⁻¹⁰
10⁻¹¹
10⁻¹²
10⁰
10¹
10²
10³
2s²2p² ³P ->
Δ = 2s2p³ ⁵S
× = 2s2p³ ¹P
Recommended Data
Chebychev Fit

Electron-Impact Excitation Rate Coefficients for
$e^- + O^{2+}$ (C-like)

Maxwellian Rate Coefficients (cm^3/s)

e^- Temp. (eV)	$2s^22p^2\ ^3P - 2s2p^3\ ^3S$ (E_{th} = 24.4 eV)	$2s^22p^2\ ^3P - 2s2p^3\ ^3D$ (E_{th} = 14.9 eV)
2.0E+00		2.66E-11
4.0E+00	3.69E-11	7.87E-10
7.0E+00	4.18E-10	3.00E-09
1.0E+01	1.07E-09	4.83E-09
2.0E+01	3.04E-09	7.57E-09
4.0E+01	4.84E-09	8.37E-09
7.0E+01	5.62E-09	8.04E-09
1.0E+02	5.81E-09	7.61E-09
2.0E+02	5.66E-09	6.58E-09
4.0E+02	5.11E-09	5.53E-09
7.0E+02	4.53E-09	4.73E-09
1.0E+03	4.15E-09	4.26E-09
2.0E+03	3.42E-09	3.44E-09
4.0E+03	2.77E-09	2.74E-09
7.0E+03	2.30E-09	2.27E-09
1.0E+04	2.04E-09	2.00E-09
2.0E+04	1.59E-09	1.56E-09
Accuracy:	20%	20%

References: T.77, T.78, T.79, T.80, T.98, T.99, T.100, T.101, T.102, T.103

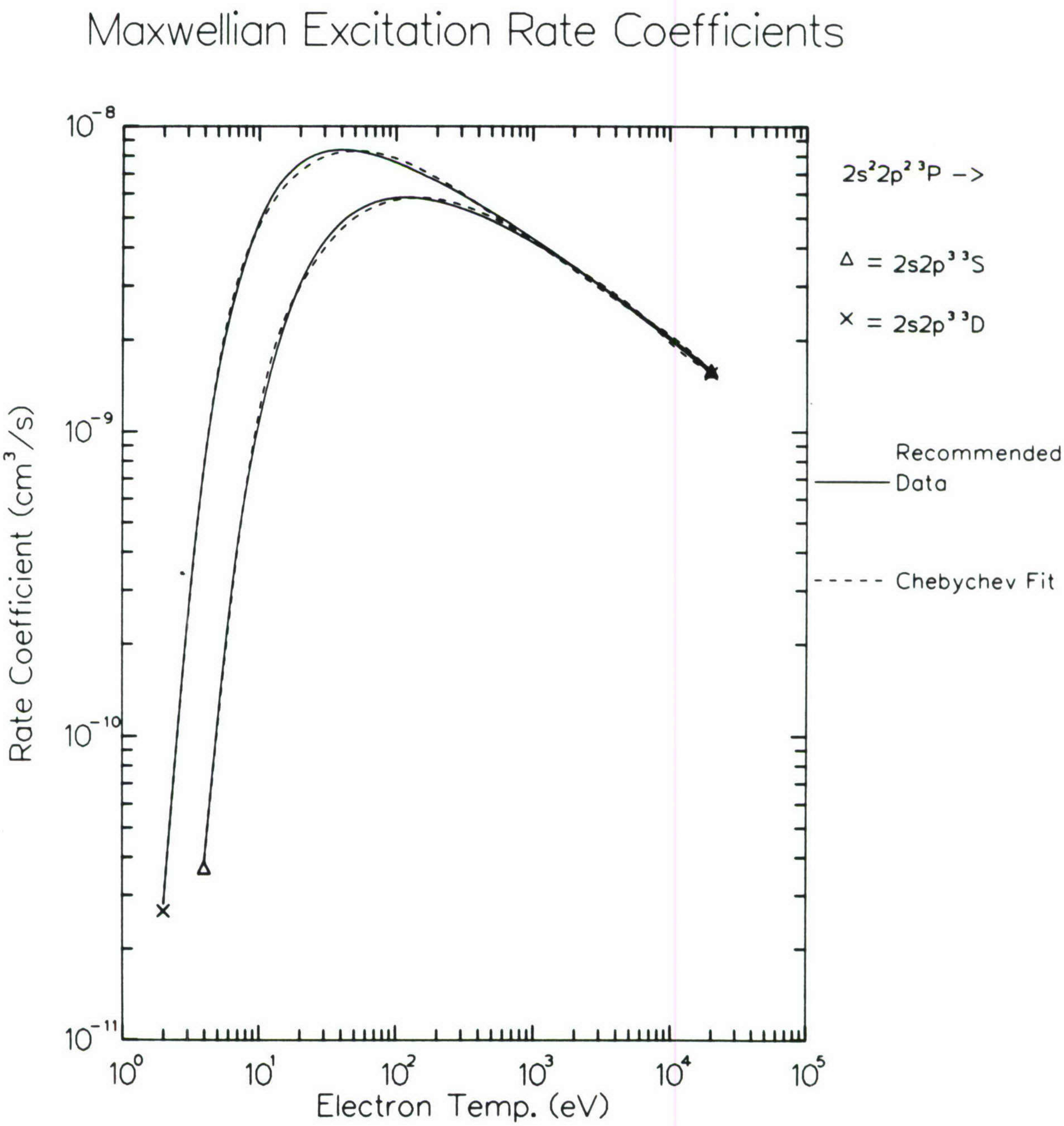
Notes: The recommended excitation-rate data for O^{2+} from the compilation [T.77] were based on close-coupling [T.98, T.99, T.100] and distorted-wave [T.79, T.80, T.102] calculations. This work has been updated in compilation [T.103] to take into account recent 12-term level-to-level close-coupling calculations [T.101] which have also been recommended in compilation [T.78].

Chebychev Fitting Parameters for Rate Coefficients

E_{min} (eV)	E_{max} (eV)	C1	C2	C3	C4	C5	C6	C7
($2s^22p^2\ ^3P - 2s2p^3\ ^3S$)								
4.0	2.0E+04	5.40611E-09	5.34806E-10	-2.41516E-09	6.14230E-10	4.76853E-10	-3.74063E-10	4.71487E-11
($2s^22p^2\ ^3P - 2s2p^3\ ^3D$)								
2.0	2.0E+04	6.84484E-09	3.16254E-11	-3.34375E-09	1.48723E-09	3.49372E-10	-7.50676E-10	3.66716E-10

See appendix for Chebychev fit details.

$e^- + O^{2+}$ (C-like)


Maxwellian Excitation Rate Coefficients
Rate Coefficient (cm³/s)
Electron Temp. (eV)
10⁻⁸
10⁻⁹
10⁻¹⁰
10⁻¹¹
10⁰
10¹
10²
10³
10⁴
10⁵
2s²2p² ³P ->
Δ = 2s2p³ ³S
× = 2s2p³ ³D
Recommended Data
Chebychev Fit

Electron-Impact Excitation Rate Coefficients for
$e^- + O^{2+}$ (C-like)

Maxwellian Rate Coefficients (cm^3/s)

e^- Temp. (eV)	$2s^22p^2\ ^3P - 2s2p^3\ ^3P$ (E_{th} = 17.6 eV)	$2s^22p^2\ ^3P - 2s2p^3\ ^1D$ (E_{th} = 23.2 eV)
2.0E+00	5.07E-12	
4.0E+00	3.08E-10	6.68E-12
7.0E+00	1.62E-09	5.69E-11
1.0E+01	3.02E-09	1.22E-10
2.0E+01	5.74E-09	2.37E-10
4.0E+01	7.25E-09	2.36E-10
7.0E+01	7.52E-09	1.78E-10
1.0E+02	7.40E-09	1.36E-10
2.0E+02	6.77E-09	7.08E-11
4.0E+02	5.91E-09	3.27E-11
7.0E+02	5.16E-09	1.65E-11
1.0E+03	4.70E-09	1.04E-11
2.0E+03	3.85E-09	3.99E-12
4.0E+03	3.10E-09	1.39E-12
7.0E+03	2.58E-09	
1.0E+04	2.28E-09	
2.0E+04	1.78E-09	
Accuracy:	20%	50%

References: T.77, T.78, T.79, T.80, T.98, T.99, T.100, T.101, T.102, T.103

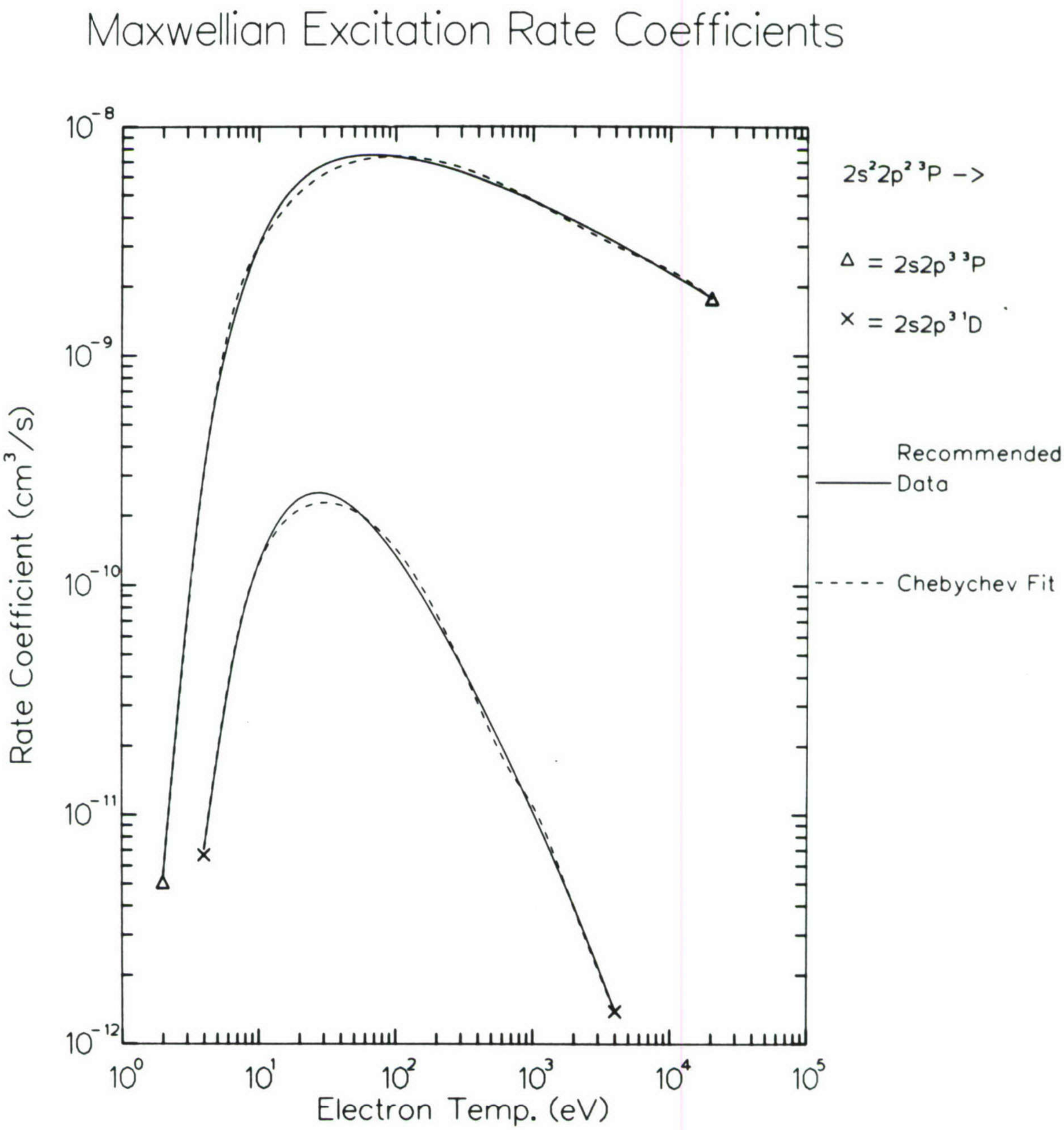
Notes: The recommended excitation-rate data for O^{2+} from the compilation [T.77] were based on close-coupling [T.98, T.99, T.100] and distorted-wave [T.79, T.80, T.102] calculations. This work has been updated in compilation [T.103] to take into account recent 12-term level-to-level close-coupling calculations [T.101] which have also been recommended in compilation [T.78].

Chebychev Fitting Parameters for Rate Coefficients

E_{min} (eV)	E_{max} (eV)	C1	C2	C3	C4	C5	C6	C7
($2s^22p^2\ ^3P - 2s2p^3\ ^3P$)								
2.0	2.0E+04	6.42259E-09	6.73954E-10	-3.12319E-09	7.68799E-10	7.51247E-10	-5.61476E-10	4.69990E-11
($2s^22p^2\ ^3P - 2s2p^3\ ^1D$)								
4.0	4.0E+03	1.34617E-10	-4.70888E-11	-7.06249E-11	6.73540E-11	-5.00097E-12	-2.29064E-11	1.23467E-11

See appendix for Chebychev fit details.

$e^- + O^{2+}$ (C-like)



Maxwellian Excitation Rate Coefficients
Rate Coefficient (cm³/s)
Electron Temp. (eV)
10^{-8}
10^{-9}
10^{-10}
10^{-11}
10^{-12}
10^0
10^1
10^2
10^3
10^4
10^5
$2s^22p^2\,^3P$ ->
Δ = $2s2p^3\,^3P$
× = $2s2p^3\,^1D$
Recommended Data
Chebychev Fit

Electron-Impact Excitation Rate Coefficients for $e^- + O^{2+}$ (C-like)

Maxwellian Rate Coefficients (cm^3/s)

e^- Temp. (eV)	$2s^22p^2\ ^1D - 2s^22p^2\ ^1S$ (E_{th} = 2.84 eV)	$2s^22p^2\ ^1D - 2s2p^3\ ^3D$ (E_{th} = 12.4 eV)	$2s^22p^2\ ^1D - 2s2p^3\ ^3P$ (E_{th} = 15.1 eV)
1.0E+00	5.70E-10		
2.0E+00	1.78E-09	3.51E-11	2.55E-12
4.0E+00	2.39E-09	5.32E-10	8.39E-11
7.0E+00	2.20E-09	1.42E-09	3.22E-10
1.0E+01	1.94E-09	1.91E-09	4.94E-10
2.0E+01	1.44E-09	2.15E-09	6.24E-10
4.0E+01	1.08E-09	1.67E-09	4.86E-10
7.0E+01	8.21E-10	1.17E-09	3.22E-10
1.0E+02	7.10E-10	8.88E-10	2.30E-10
2.0E+02		4.86E-10	1.04E-10
4.0E+02		2.54E-10	
7.0E+02		1.49E-10	
1.0E+03		1.07E-10	
Accuracy:	50%	50%	50%

References: T.77, T.78, T.79, T.80, T.98, T.99, T.100, T.101, T.102, T.103

Notes: The recommended excitation-rate data for O^{2+} from the compilation [T.77] were based on close-coupling [T.98, T.99, T.100] and distorted-wave [T.79, T.80, T.102] calculations. This work has been updated in compilation [T.103] to take into account recent 12-term level-to-level close-coupling calculations [T.101] which have also been recommended in compilation [T.78].

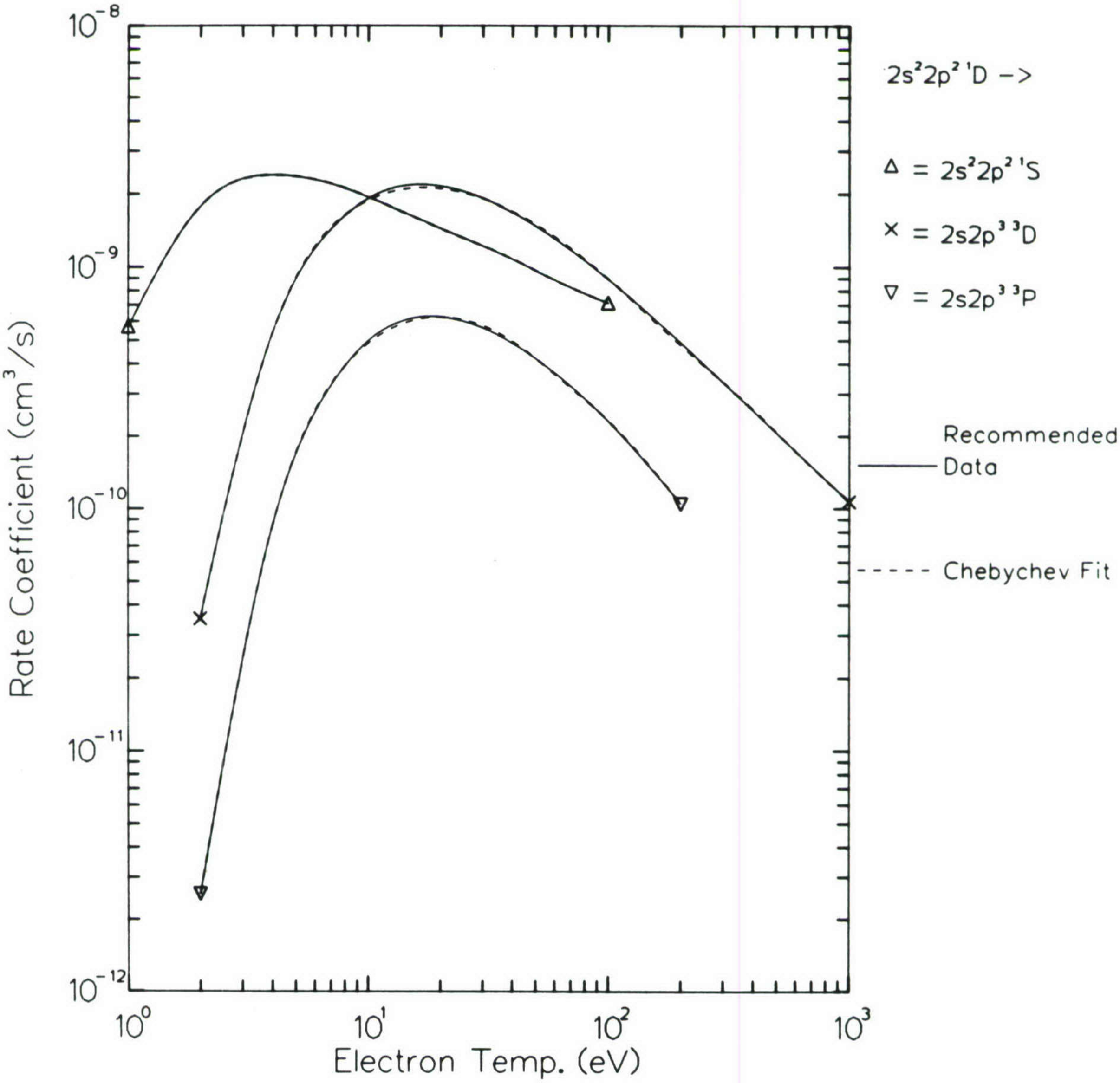
Chebychev Fitting Parameters for Rate Coefficients

E_{min} (eV)	E_{max} (eV)	C1	C2	C3	C4	C5	C6	C7
($2s^22p^2\ ^1D - 2s^22p^2\ ^1S$)								
1.0	1.0E+02	2.64673E-09	-2.41088E-10	-7.01602E-10	3.93090E-10	-3.29629E-11	-8.16234E-11	5.14021E-11
($2s^22p^2\ ^1D - 2s2p^3\ ^3D$)								
2.0	1.0E+03	1.41048E-09	-2.09731E-10	-8.38177E-10	4.69539E-10	1.26959E-10	-2.23951E-10	7.69328E-11
($2s^22p^2\ ^1D - 2s2p^3\ ^3P$)								
2.0	2.0E+02	4.90810E-10	7.87983E-11	-2.65175E-10	-5.49815E-12	9.24612E-11	-2.24286E-11	-1.92686E-11

See appendix for Chebychev fit details.

$e^- + O^{2+}$ (C-like)

Maxwellian Excitation Rate Coefficients



Electron-Impact Excitation Rate Coefficients for
$e^- + O^{2+}$ (C-like)

Maxwellian Rate Coefficients (cm^3/s)

e^- Temp. (eV)	$2s^22p^2\ ^1S - 2s2p^3\ ^3P$ (E_{th} = 12.3 eV)	$2s^22p^2\ ^1S - 2s2p^3\ ^3D$ (E_{th} = 9.53 eV)	$2s2p^3\ ^3D - 2s2p^3\ ^3P$ (E_{th} = 2.78 eV)
1.0E+00	1.08E-13	6.95E-13	1.57E-09
2.0E+00	3.46E-11	4.83E-11	4.42E-09
4.0E+00	5.20E-10	2.83E-10	6.06E-09
7.0E+00	1.45E-09	4.54E-10	5.91E-09
1.0E+01	2.02E-09	4.71E-10	5.38E-09
2.0E+01	2.49E-09	3.53E-10	4.06E-09
4.0E+01	2.10E-09	1.94E-10	2.85E-09
7.0E+01	1.54E-09	1.02E-10	2.11E-09
1.0E+02	1.19E-09	6.40E-11	1.73E-09
2.0E+02	6.59E-10	2.15E-11	1.19E-09
4.0E+02	3.34E-10		8.21E-10
7.0E+02	1.84E-10		6.12E-10
1.0E+03	1.25E-10		5.09E-10
Accuracy:	100%	50%	100%

References: T.77, T.78, T.79, T.80, T.98, T.99, T.100, T.101, T.102, T.103

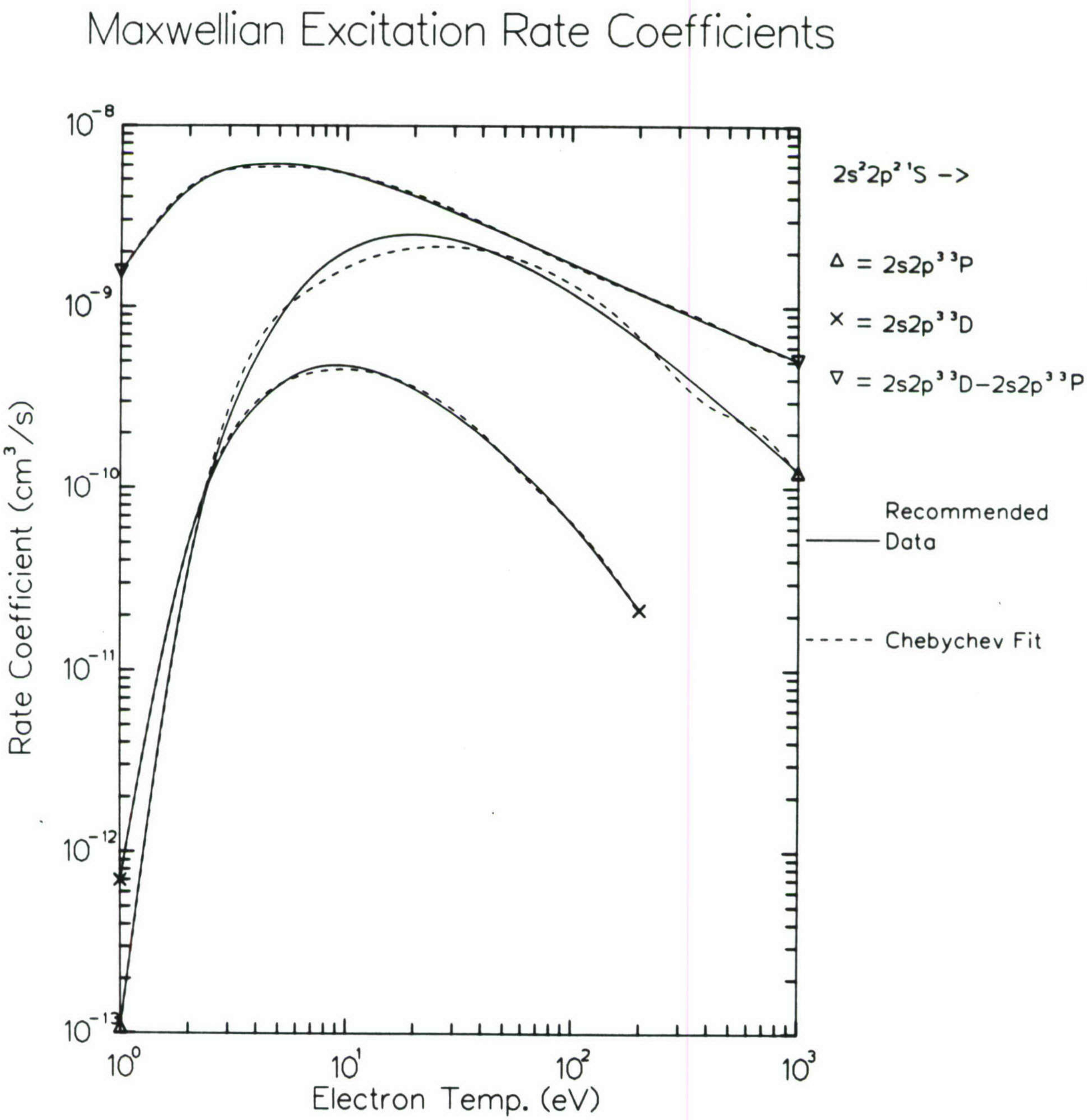
Notes: The recommended excitation-rate data for O^{2+} from the compilation [T.77] were based on close-coupling [T.98, T.99, T.100] and distorted-wave [T.79, T.80, T.102] calculations. This work has been updated in compilation [T.103] to take into account recent 12-term level-to-level close-coupling calculations [T.101] which have also been recommended in compilation [T.78].

Chebychev Fitting Parameters for Rate Coefficients

E_{min} (eV)	E_{max} (eV)	C1	C2	C3	C4	C5	C6	C7
($2s^22p^2\ ^1S - 2s2p^3\ ^3P$)								
1.0	1.0E+03	1.37918E-09	5.67468E-11	-9.58850E-10	9.51530E-11	4.04896E-10	-9.08810E-11	-7.45091E-11
($2s^22p^2\ ^1S - 2s2p^3\ ^3D$)								
1.0	2.0E+02	2.90561E-10	3.41724E-12	-2.04180E-10	4.87148E-11	7.19741E-11	-4.17143E-11	-1.96119E-12
($2s2p^3\ ^3D - 2s2p^3\ ^3P$)								
1.0	1.0E+03	5.29632E-09	-1.84274E-09	-1.22310E-09	1.37284E-09	-4.69870E-10	-5.65554E-11	8.31755E-11

See appendix for Chebychev fit details.

$e^- + O^{2+}$ (C–like)



Maxwellian Excitation Rate Coefficients
Rate Coefficient (cm³/s)
Electron Temp. (eV)
2s²2p² ¹S ->
Δ = 2s2p³ ³P
× = 2s2p³ ³D
∇ = 2s2p³ ³D–2s2p³ ³P
Recommended Data
Chebychev Fit

Electron-Impact Excitation Rate Coefficients for $e^- + O^{2+}$ (C-like)

Maxwellian Rate Coefficients (cm^3/s)

e^- Temp. (eV)	$2s2p^3\ ^5S - 2s2p^3\ ^3D$ (E_{th} = 7.40 eV)	$2s2p^3\ ^5S - 2s2p^3\ ^3P$ (E_{th} = 10.2 eV)
1.0E+00	2.25E-11	3.96E-13
2.0E+00	6.40E-10	4.61E-11
4.0E+00	2.82E-09	4.25E-10
7.0E+00	4.58E-09	9.66E-10
1.0E+01	5.14E-09	1.24E-09
2.0E+01	4.84E-09	1.36E-09
4.0E+01	3.20E-09	1.05E-09
Accuracy:	50%	50%

References: T.77, T.78, T.79, T.80, T.98, T.99, T.100, T.101, T.102, T.103

Notes: The recommended excitation-rate data for O^{2+} from the compilation [T.77] were based on close-coupling [T.98, T.99, T.100] and distorted-wave [T.79, T.80, T.102] calculations. This work has been updated in compilation [T.103] to take into account recent 12-term level-to-level close-coupling calculations [T.101] which have also been recommended in compilation [T.78].

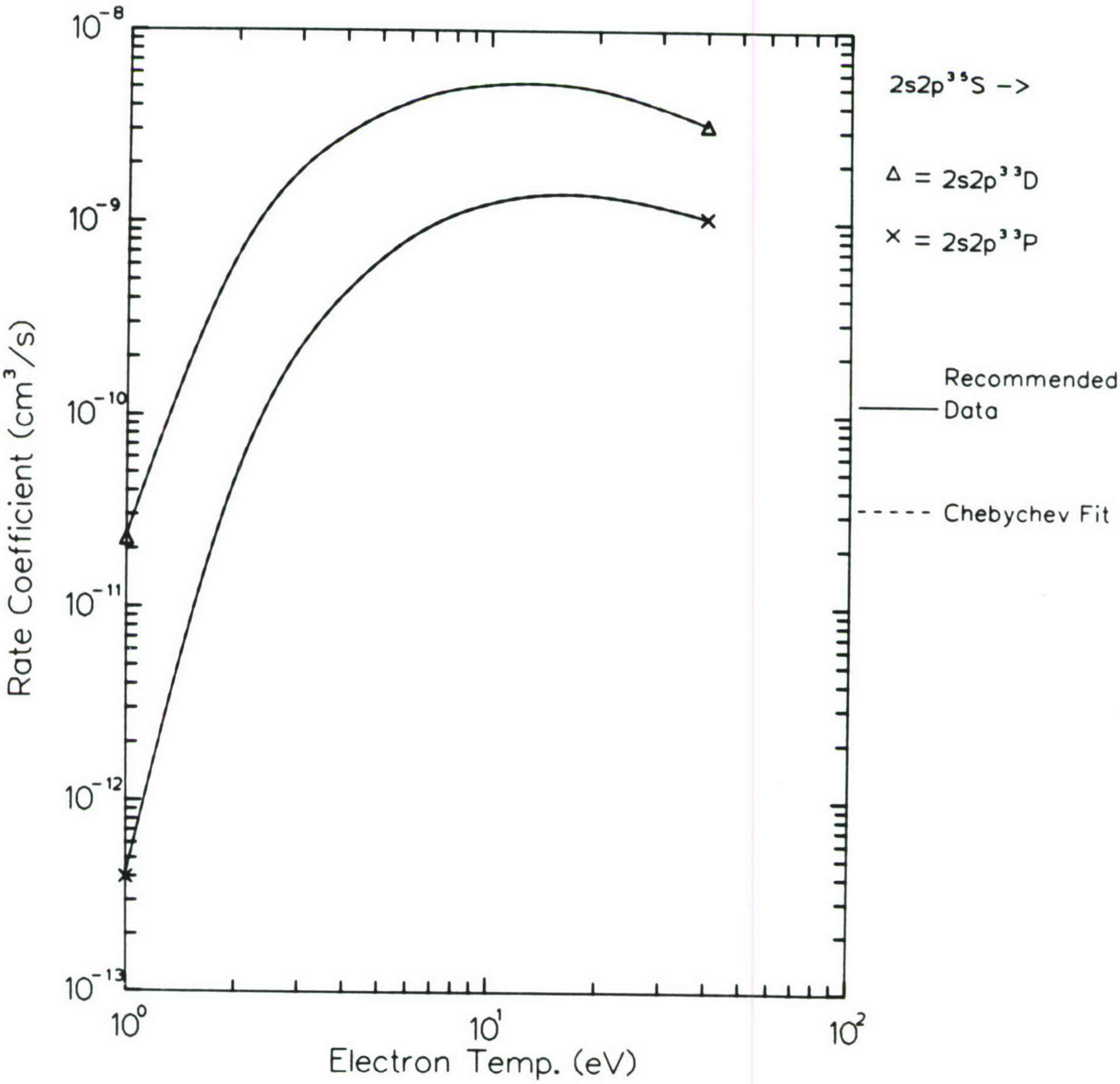
Chebychev Fitting Parameters for Rate Coefficients

E_{min} (eV)	E_{max} (eV)	C1	C2	C3	C4	C5	C6	C7
($2s2p^3\ ^5S - 2s2p^3\ ^3D$)								
1.0	4.0E+01	5.45934E-09	2.28227E-09	-1.27222E-09	-7.67916E-10	2.39708E-10	7.20009E-11	-8.83088E-11
($2s2p^3\ ^5S - 2s2p^3\ ^3P$)								
1.0	4.0E+01	1.37554E-09	7.14737E-10	-1.59206E-10	-2.52237E-10	9.92073E-12	6.15517E-11	-1.40371E-11

See appendix for Chebychev fit details.

$e^- + O^{2+}$ (C-like)

Maxwellian Excitation Rate Coefficients



Electron-Impact Excitation Rate Coefficients for $e^- + O^{3+}$ (B-like)

Maxwellian Rate Coefficients (cm^3/s)

e^- Temp. (eV)	$2s^22p\ ^2P - 2s2p^2\ ^2P$ (E_{th} = 22.4 eV)	$2s^22p\ ^2P - 2s2p^2\ ^4P$ (E_{th} = 8.82 eV)
2.0E+00	9.18E-13	1.07E-14
4.0E+00	1.79E-10	8.56E-12
7.0E+00	1.55E-09	1.23E-10
1.0E+01	3.51E-09	3.23E-10
2.0E+01	8.41E-09	7.90E-10
4.0E+01	1.20E-08	9.42E-10
7.0E+01	1.34E-08	8.45E-10
1.0E+02	1.36E-08	7.46E-10
2.0E+02	1.31E-08	5.55E-10
4.0E+02	1.19E-08	4.03E-10
7.0E+02	1.07E-08	3.10E-10
1.0E+03	9.92E-09	2.62E-10
2.0E+03	8.33E-09	
4.0E+03	6.85E-09	
7.0E+03	5.76E-09	
1.0E+04	5.14E-09	
2.0E+04	4.07E-09	
Accuracy:	30%	30%

References: T.77, T.79, T.80, T.104, T.105

Notes: The recommended excitation-rate date for O^{3+} are from the compilation [T.77], and were based on close-coupling [T.104] and distorted-wave [T.79, T.80] calculations. The recent level-to-level close-coupling calculation [T.105] for transitions between the lowest terms are consistent with these recommended data.

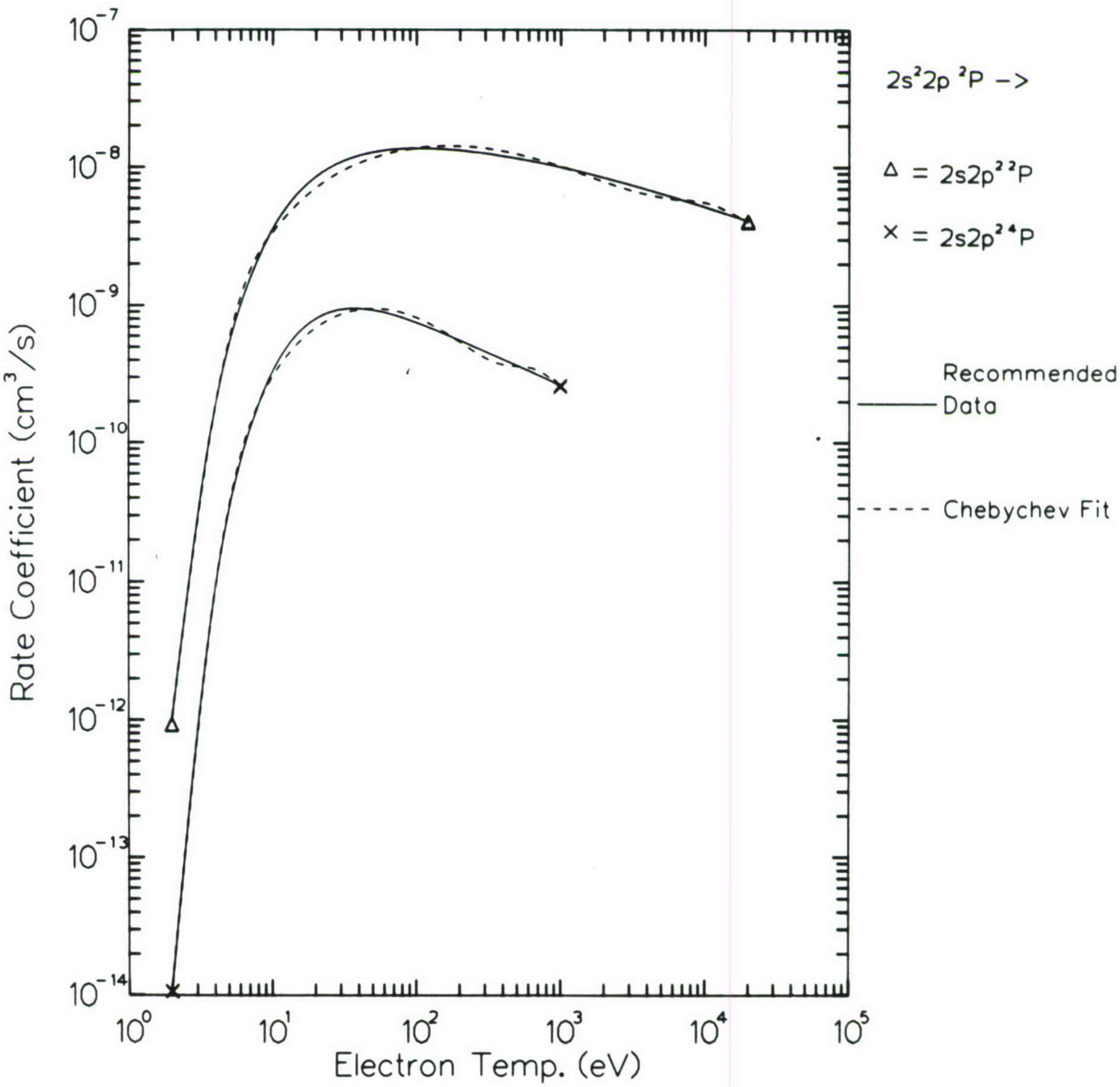
Chebychev Fitting Parameters for Rate Coefficients

E_{min} (eV)	E_{max} (eV)	C1	C2	C3	C4	C5	C6	C7
($2s^22p\ ^2P - 2s2p^2\ ^2P$)								
2.0	2.0E+04	1.21371E-08	2.35292E-09	-5.58626E-09	4.04461E-10	1.98241E-09	-7.65827E-10	-4.72257E-10
($2s^22p\ ^2P - 2s2p^2\ ^4P$)								
2.0	1.0E+03	7.32557E-10	1.81064E-10	-3.43598E-10	-4.21541E-11	1.65053E-10	-1.16467E-11	-6.04605E-11

See appendix for Chebychev fit details.

$e^- + O^{3+}$ (B-like)

Maxwellian Excitation Rate Coefficients



Electron-Impact Excitation Rate Coefficients for $e^- + O^{3+}$ (B-like)

Maxwellian Rate Coefficients (cm^3/s)

e^- Temp. (eV)	$2s^22p\ ^2P - 2s2p^2\ ^2D$ (E_{th} = 15.7 eV)	$2s^22p\ ^2P - 2s2p^2\ ^2S$ (E_{th} = 20.4 eV)
2.0E+00	2.08E-11	
4.0E+00	7.61E-10	9.01E-11
7.0E+00	3.17E-09	6.21E-10
1.0E+01	5.33E-09	1.28E-09
2.0E+01	8.84E-09	2.70E-09
4.0E+01	1.02E-08	3.55E-09
7.0E+01	1.02E-08	3.73E-09
1.0E+02	9.78E-09	3.68E-09
2.0E+02	8.71E-09	3.38E-09
4.0E+02	7.48E-09	2.95E-09
7.0E+02	6.48E-09	2.58E-09
1.0E+03	5.88E-09	2.35E-09
2.0E+03	4.79E-09	1.93E-09
4.0E+03	3.85E-09	1.55E-09
7.0E+03	3.19E-09	1.29E-09
1.0E+04	2.82E-09	1.14E-09
2.0E+04	2.20E-09	8.95E-10
Accuracy:	30%	30%

References: T.77, T.79, T.80, T.104, T.105

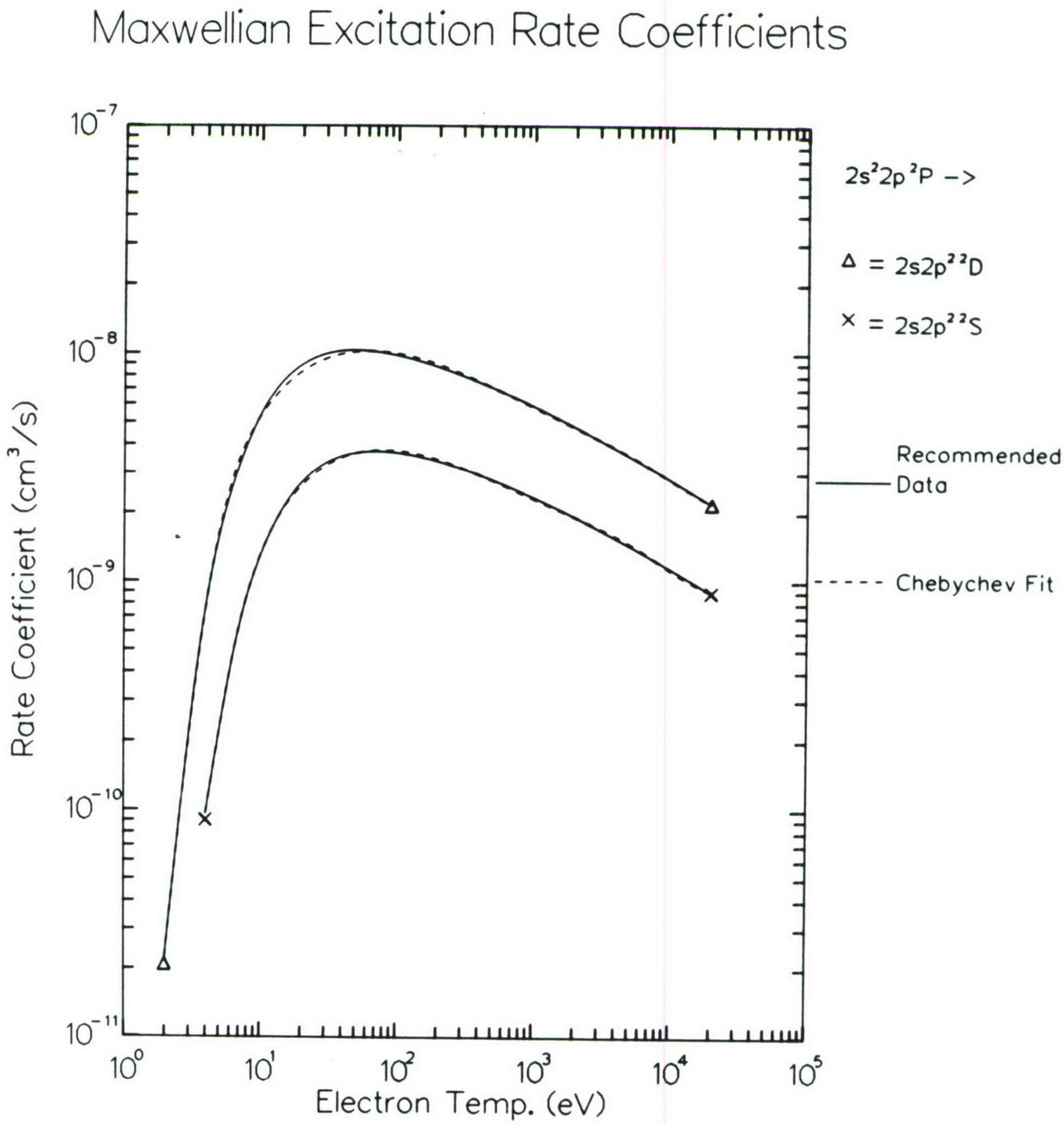
Notes: The recommended excitation-rate date for O^{3+} are from the compilation [T.77], and were based on close-coupling [T.104] and distorted-wave [T.79, T.80] calculations. The recent level-to-level close-coupling calculation [T.105] for transitions between the lowest terms are consistent with these recommended data.

Chebychev Fitting Parameters for Rate Coefficients

E_{min} (eV)	E_{max} (eV)	C1	C2	C3	C4	C5	C6	C7
($2s^22p\ ^2P - 2s2p^2\ ^2D$)								
2.0	2.0E+04	8.75726E-09	4.23730E-10	-4.24537E-09	1.53835E-09	6.43585E-10	-8.70660E-10	3.35408E-10
($2s^22p\ ^2P - 2s2p^2\ ^2S$)								
4.0	2.0E+04	3.52485E-09	7.07366E-12	-1.48024E-09	6.34309E-10	8.44096E-11	-2.37563E-10	1.27330E-10

See appendix for Chebychev fit details.

$e^- + O^{3+}$ (B-like)


Maxwellian Excitation Rate Coefficients
10^{-7}
10^{-8}
10^{-9}
10^{-10}
10^{-11}
Rate Coefficient (cm^3/s)
10^0
10^1
10^2
10^3
10^4
10^5
Electron Temp. (eV)
$2s^22p\,^2P$ ->
Δ = $2s2p^2\,^2D$
× = $2s2p^2\,^2S$
Recommended Data
Chebychev Fit

Electron-Impact Excitation Rate Coefficients for
$e^- + O^{3+}$ (B-like)

Maxwellian Rate Coefficients (cm^3/s)

e^- Temp. (eV)	$2s2p^2\ ^4P - 2s2p^2\ ^2D$ (E_{th} = 6.89 eV)	$2s2p^2\ ^4P - 2s2p^2\ ^2P$ (E_{th} = 13.5 eV)	$2s2p^2\ ^4P - 2s2p^2\ ^2S$ (E_{th} = 11.5 eV)
1.0E+00	2.21E-11		
2.0E+00	4.78E-10	8.50E-12	5.97E-12
4.0E+00	1.81E-09	2.00E-10	7.29E-11
7.0E+00	2.72E-09	4.19E-10	1.81E-10
1.0E+01	2.92E-09	5.01E-10	2.37E-10
2.0E+01	2.55E-09	5.28E-10	2.61E-10
4.0E+01	1.74E-09	3.50E-10	1.97E-10
7.0E+01	1.11E-09	2.09E-10	1.31E-10
1.0E+02	7.93E-10	1.41E-10	9.40E-11
2.0E+02	3.74E-10	5.81E-11	4.42E-11
4.0E+02	1.60E-10	2.41E-11	1.86E-11
7.0E+02	7.65E-11	1.16E-11	8.76E-12
1.0E+03	4.69E-11	7.09E-12	5.33E-12
Accuracy:	50%	50%	50%

References: T.77, T.79, T.80, T.104, T.105

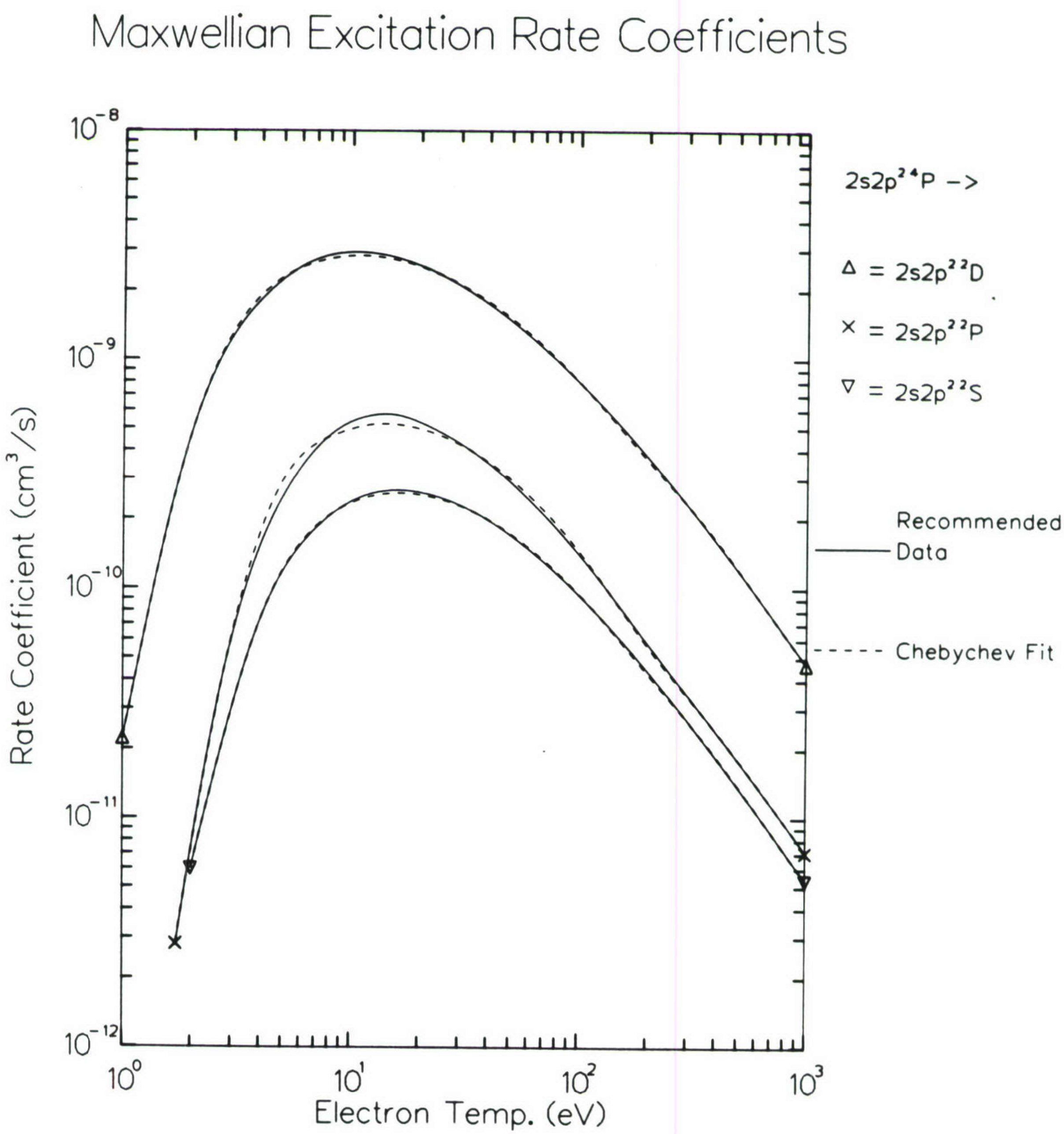
Notes: The recommended excitation-rate date for O^{3+} are from the compilation [T.77], and were based on close-coupling [T.104] and distorted-wave [T.79, T.80] calculations. The recent level-to-level close-coupling calculation [T.105] for transitions between the lowest terms are consistent with these recommended data.

Chebychev Fitting Parameters for Rate Coefficients

E_{min} (eV)	E_{max} (eV)	C1	C2	C3	C4	C5	C6	C7
($2s2p^2\ ^4P - 2s2p^2\ ^2D$)								
1.0	1.0E+03	1.702203E-09	-3.311509E-10	-1.114679E-09	6.725835E-10	1.919384E-10	-3.290272E-10	1.061579E-10
($2s2p^2\ ^4P - 2s2p^2\ ^2P$)								
1.7	1.0E+03	3.06179E-10	-7.38677E-11	-1.92221E-10	1.37015E-10	2.24772E-11	-6.10105E-11	2.16022E-11
($2s2p^2\ ^4P - 2s2p^2\ ^2S$)								
2.0	1.0E+03	1.63959E-10	-3.52285E-11	-9.92097E-11	6.23652E-11	1.36780E-11	-2.74559E-11	9.20262E-12

See appendix for Chebychev fit details.

$e^- + O^{3+}$ (B-like)



Maxwellian Excitation Rate Coefficients
10^{-8}
10^{-9}
10^{-10}
10^{-11}
10^{-12}
Rate Coefficient (cm^3/s)
10^0
10^1
10^2
10^3
Electron Temp. (eV)
$2s2p^{2\,4}P$ ->
Δ = $2s2p^{2\,2}D$
× = $2s2p^{2\,2}P$
∇ = $2s2p^{2\,2}S$
Recommended Data
Chebychev Fit

Electron-Impact Excitation Rate Coefficients for
$e^- + O^{3+}$ (B-like)

Maxwellian Rate Coefficients (cm^3/s)

e^- Temp. (eV)	$2s2p^2\ ^2D - 2s2p^2\ ^2S$ (E_{th} = 4.64 eV)	$2s2p^2\ ^2D - 2s2p^2\ ^2P$ (E_{th} = 6.65 eV)	$2s2p^2\ ^2S - 2s2p^2\ ^2P$ (E_{th} = 2.01 eV)
1.0E+00	4.90E-11	1.61E-11	1.31E-09
2.0E+00	3.59E-10	3.12E-10	2.51E-09
4.0E+00	8.24E-10	1.14E-09	2.88E-09
7.0E+00	1.04E-09	1.69E-09	2.61E-09
1.0E+01	1.07E-09	1.81E-09	2.29E-09
2.0E+01	9.88E-10	1.60E-09	1.59E-09
4.0E+01	8.29E-10	1.10E-09	9.71E-10
7.0E+01	7.00E-10	7.18E-10	5.97E-10
1.0E+02	6.25E-10	5.19E-10	4.22E-10
2.0E+02	4.98E-10	2.51E-10	1.99E-10
4.0E+02	3.95E-10	1.10E-10	8.47E-11
7.0E+02	3.26E-10	5.30E-11	4.02E-11
1.0E+03	2.88E-10	3.26E-11	2.45E-11
Accuracy:	50%	50%	50%

References: T.77, T.79, T.80, T.104, T.105

Notes: The recommended excitation-rate date for O^{3+} are from the compilation [T.77], and were based on close-coupling [T.104] and distorted-wave [T.79, T.80] calculations. The recent level-to-level close-coupling calculation [T.105] for transitions between the lowest terms are consistent with these recommended data.

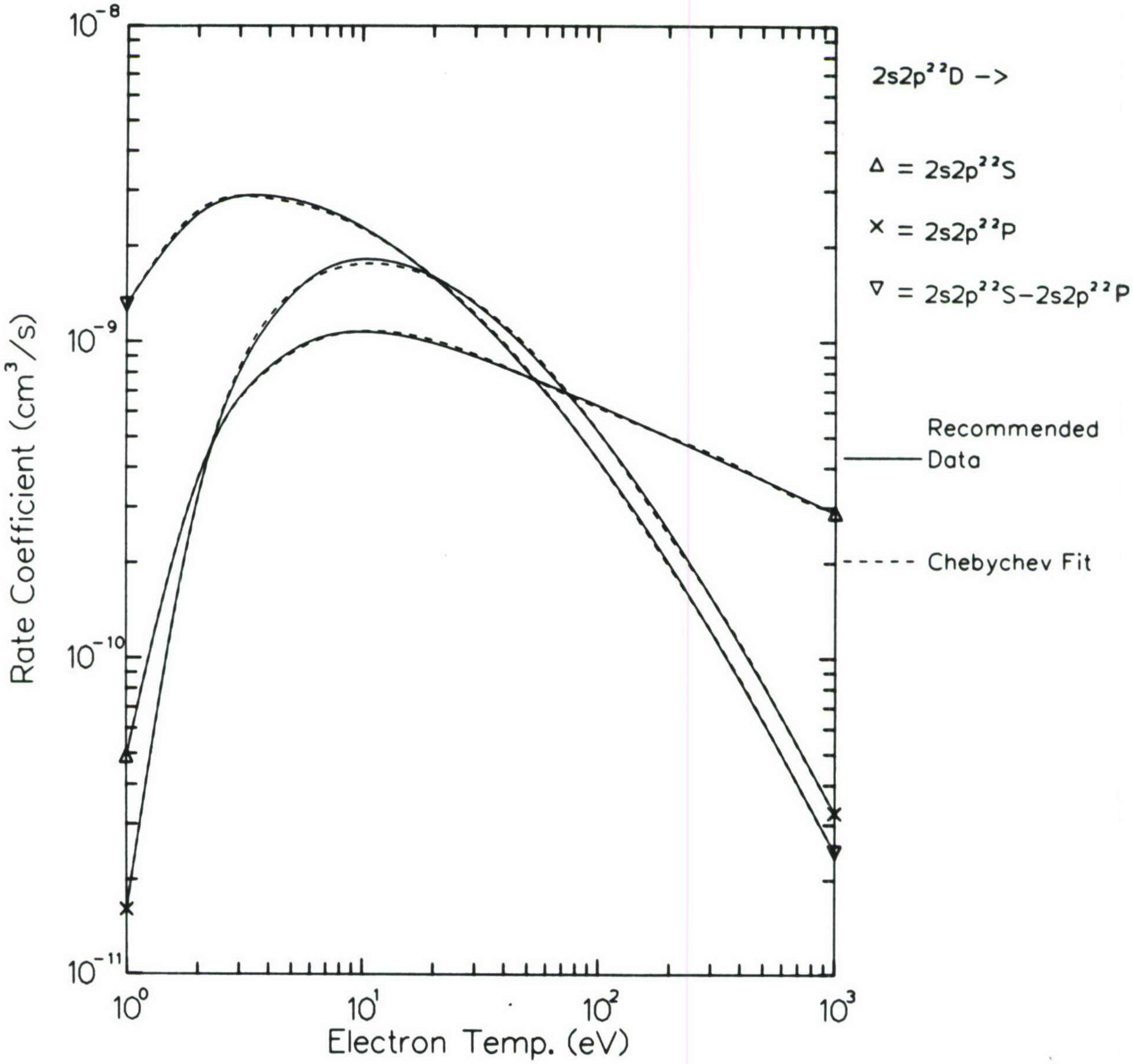
Chebychev Fitting Parameters for Rate Coefficients

E_{min} (eV)	E_{max} (eV)	C1	C2	C3	C4	C5	C6	C7
($2s2p^2\ ^2D - 2s2p^2\ ^2S$)								
1.0	1.0E+03	1.03218E-09	1.10320E-12	-3.98983E-10	1.88731E-10	1.75772E-11	-6.96737E-11	3.44717E-11
($2s2p^2\ ^2D - 2s2p^2\ ^2P$)								
1.0	1.0E+03	1.08123E-09	-2.05632E-10	-6.99149E-10	4.12881E-10	1.19245E-10	-1.98967E-10	6.36224E-11
($2s2p^2\ ^2S - 2s2p^2\ ^2P$)								
1.0	1.0E+03	2.37049E-09	-1.27489E-09	-2.69715E-10	6.11976E-10	-2.60837E-10	2.15868E-11	1.11928E-11

See appendix for Chebychev fit details.

$e^- + O^{3+}$ (B-like)

Maxwellian Excitation Rate Coefficients



Electron-Impact Excitation Rate Coefficients for $e^- + O^{4+}$ (Be-like)

Maxwellian Rate Coefficients (cm^3/s)

e^- Temp. (eV)	$2s^2\ ^1S - 2s2p\ ^1P$ (E_{th} = 19.7 eV)	$2s^2\ ^1S - 2p^2\ ^3P$ (E_{th} = 26.5 eV)	$2s^2\ ^1S - 2s2p\ ^3P$ (E_{th} = 10.2 eV)
4.0E+00	7.63E-10	4.96E-13	1.68E-09
7.0E+00	4.94E-09	6.12E-12	3.59E-09
1.0E+01	9.93E-09	1.50E-11	4.39E-09
2.0E+01	2.05E-08	3.37E-11	4.34E-09
4.0E+01	2.67E-08	3.76E-11	3.06E-09
7.0E+01	2.81E-08	3.17E-11	1.98E-09
1.0E+02	2.77E-08	2.66E-11	1.43E-09
2.0E+02	2.56E-08	1.77E-11	6.98E-10
4.0E+02	2.25E-08	1.14E-11	3.04E-10
7.0E+02	1.98E-08		1.41E-10
1.0E+03	1.80E-08		8.54E-11
2.0E+03	1.49E-08		3.32E-11
4.0E+03	1.20E-08		1.24E-11
7.0E+03	1.00E-08		5.50E-12
1.0E+04	8.91E-09		3.25E-12
2.0E+04	7.00E-09		1.16E-12
Accuracy:	20%	50%	30%

References: T.77, T.78, T.79, T.85, T.86, T.106, T.107, T.108

Notes: The recommended excitation-rate data for O^{4+} from the compilation [T.77] were based on close-coupling [T.85, T.86, T.106, T.107], Coulomb-Born-Exchange, and distorted-wave [T.79, T.80] calculations. This work has been updated to take into account recent multi-term close-coupling calculations [T.108] which have been recommended in compilation [T.78].

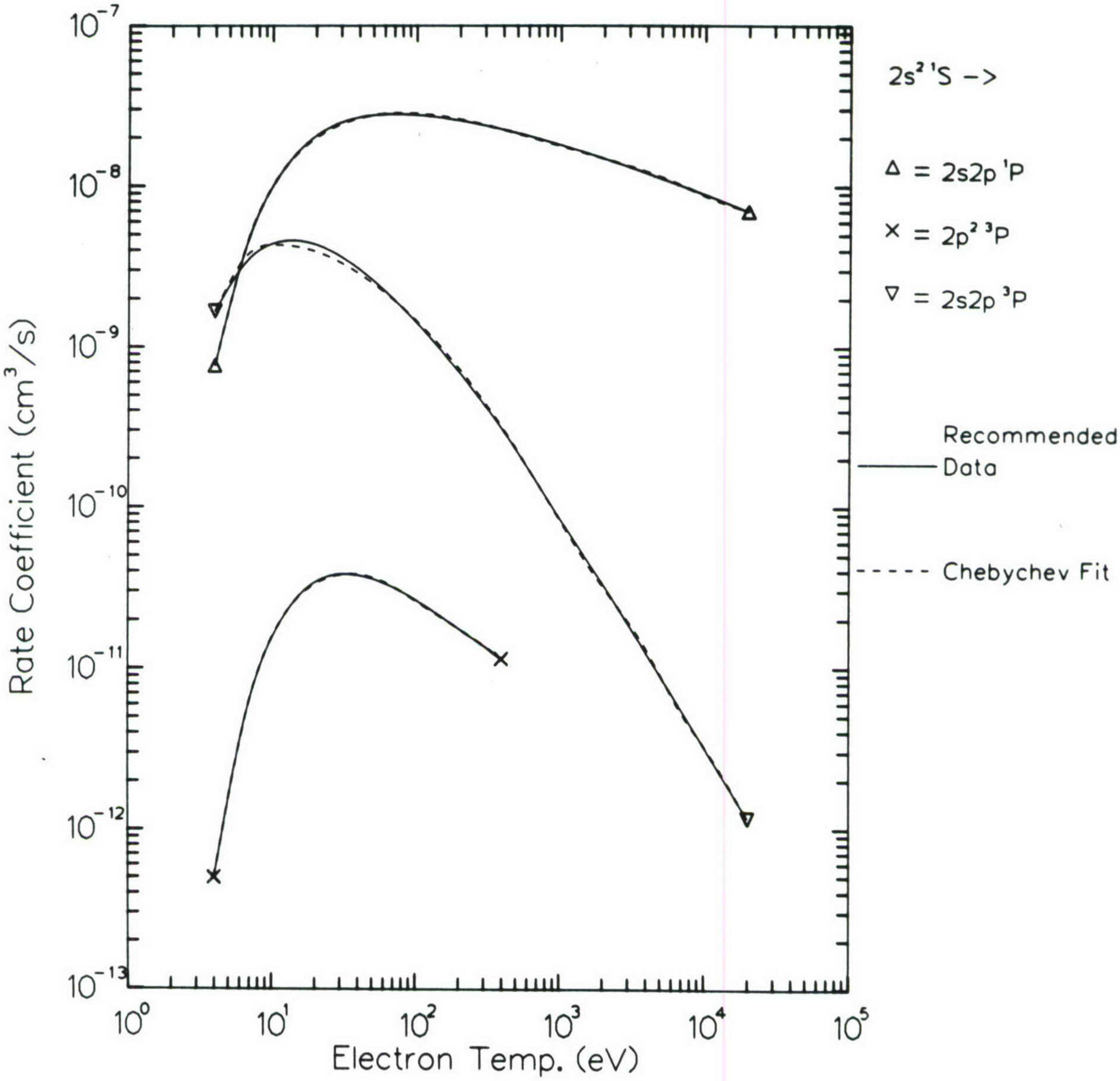
Chebychev Fitting Parameters for Rate Coefficients

E_{min} (eV)	E_{max} (eV)	C1	C2	C3	C4	C5	C6	C7
($2s^2\ ^1S - 2s2p\ ^1P$)								
4.0	2.0E+04	2.70005E-08	1.41124E-10	-1.11331E-08	4.70093E-09	5.86947E-10	-1.71254E-09	9.38540E-10
($2s^2\ ^1S - 2p^2\ ^3P$)								
4.0	4.0E+02	3.52201E-11	5.85078E-12	-1.52721E-11	1.58015E-12	4.43009E-12	-1.97013E-12	-8.10776E-13
($2s^2\ ^1S - 2s2p\ ^3P$)								
40.	2.0E+04	2.80371E-09	-1.92517E-09	2.36055E-10	7.65144E-10	-7.40586E-10	3.29038E-10	-6.51680E-11

See appendix for Chebychev fit details.

$e^- + O^{4+}$ (Be-like)

Maxwellian Excitation Rate Coefficients



Electron-Impact Excitation Rate Coefficients for $e^- + O^{4+}$ (Be-like)

Maxwellian Rate Coefficients (cm^3/s)

e^- Temp. (eV)	$2s^2\ ^1S - 2p^2\ ^1D$ (E_{th} = 28.5 eV)	$2s^2\ ^1S - 2p^2\ ^1S$ (E_{th} = 35.7 eV)
2.7E+00	1.63E-13	1.75E-15
4.0E+00	5.57E-12	1.61E-13
7.0E+00	5.77E-11	3.29E-12
1.0E+01	1.62E-10	1.29E-11
2.0E+01	4.39E-10	5.34E-11
3.0E+01	5.62E-10	8.09E-11
4.0E+01	6.04E-10	9.48E-11
5.0E+01	6.07E-10	1.00E-10
6.0E+01	5.93E-10	1.01E-10
7.0E+01	5.73E-10	9.85E-11
8.0E+01	5.52E-10	9.58E-11
9.0E+01	5.35E-10	9.35E-11
1.0E+02	5.22E-10	9.22E-11
Accuracy:	50%	50%

References: T.77, T.78, T.79, T.85, T.86, T.106, T.107, T.108

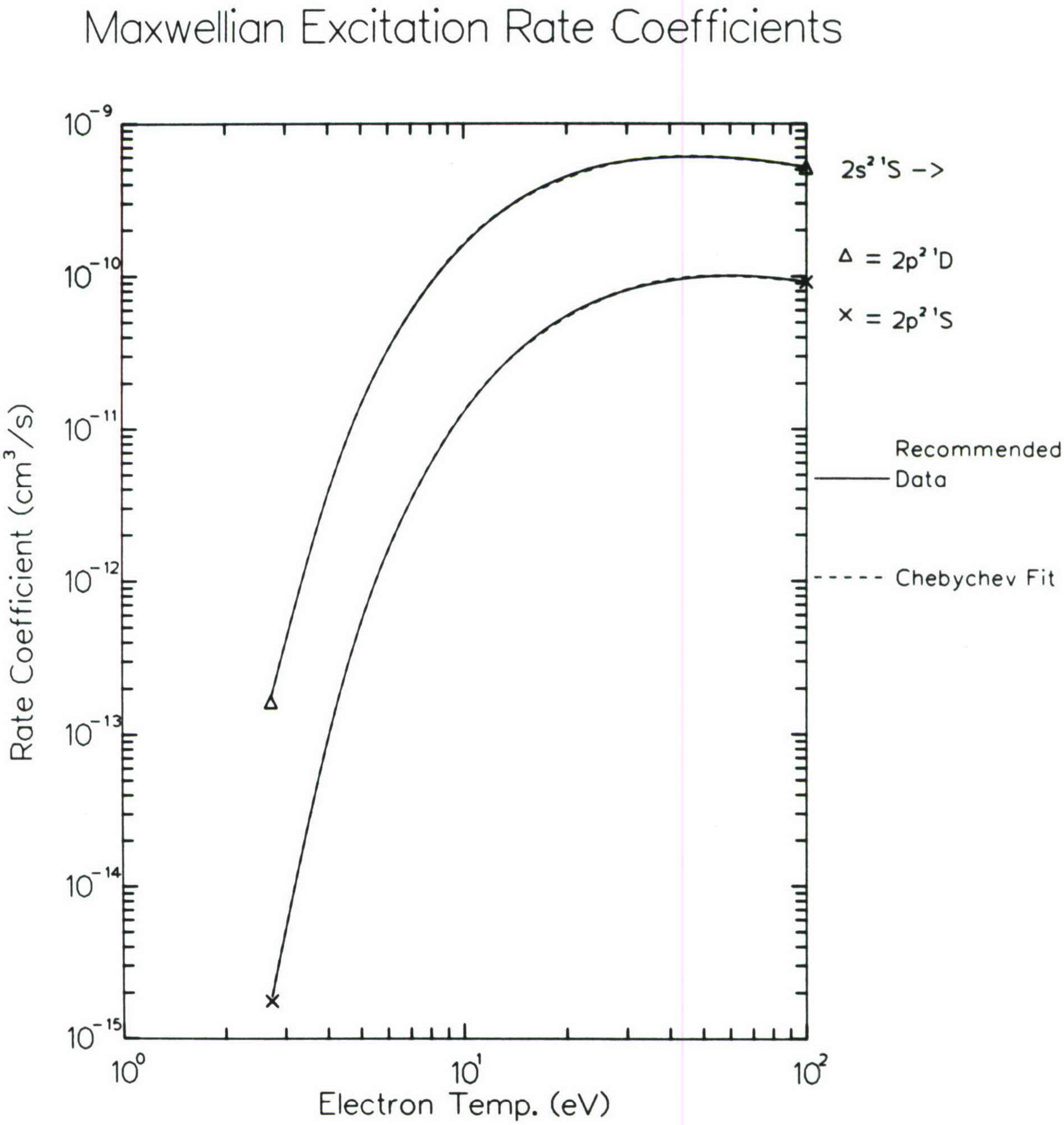
Notes: The recommended excitation-rate data for O^{4+} from the compilation [T.77] were based on close-coupling [T.85, T.86, T.106, T.107], Coulomb-Born-Exchange, and distorted-wave [T.79, T.80] calculations. This work has been updated to take into account recent multi-term close-coupling calculations [T.108] which have been recommended in compilation [T.78].

Chebychev Fitting Parameters for Rate Coefficients

E_{min} (eV)	E_{max} (eV)	C1	C2	C3	C4	C5	C6	C7
($2s^2\ ^1S - 2p^2\ ^1D$)								
2.7	1.1E+02	6.16332E-10	3.33690E-10	-5.87135E-11	-9.90009E-11	1.03586E-11	2.30042E-11	-1.95491E-12
($2s^2\ ^1S - 2p^2\ ^1S$)								
2.7	1.1E+02	9.46159E-11	5.83619E-11	2.48801E-13	-1.60225E-11	-2.85612E-12	3.79825E-12	1.43871E-12

See appendix for Chebychev fit details.

$e^- + O^{4+}$ (Be-like)


Maxwellian Excitation Rate Coefficients
Rate Coefficient (cm³/s)
10⁻⁹
10⁻¹⁰
10⁻¹¹
10⁻¹²
10⁻¹³
10⁻¹⁴
10⁻¹⁵
10⁰
10¹
10²
Electron Temp. (eV)
2s² ¹S ->
Δ = 2p² ¹D
× = 2p² ¹S
Recommended Data
Chebychev Fit

Electron-Impact Excitation Rate Coefficients for
$e^- + O^{4+}$ (Be-like)

Maxwellian Rate Coefficients (cm^3/s)

e^- Temp. (eV)	2s2p ^3P - $2p^2$ ^3P (E_{th} = 16.3 eV)	2s2p ^3P - 2s2p ^1P (E_{th} = 9.48 eV)
1.0E+00		1.06E-12
2.0E+00	2.19E-11	8.36E-11
4.0E+00	9.23E-10	6.04E-10
7.0E+00	4.09E-09	1.17E-09
1.0E+01	7.07E-09	1.34E-09
2.0E+01	1.22E-08	1.18E-09
4.0E+01	1.47E-08	7.46E-10
7.0E+01	1.49E-08	4.52E-10
1.0E+02	1.46E-08	3.18E-10
2.0E+02	1.33E-08	1.55E-10
4.0E+02	1.16E-08	7.51E-11
7.0E+02	1.01E-08	
1.0E+03	9.22E-09	
2.0E+03	7.56E-09	
4.0E+03	6.09E-09	
7.0E+03	5.06E-09	
1.0E+04	4.48E-09	
2.0E+04	3.50E-09	
Accuracy:	50%	50%

References: T.77, T.78, T.79, T.85, T.86, T.106, T.107, T.108

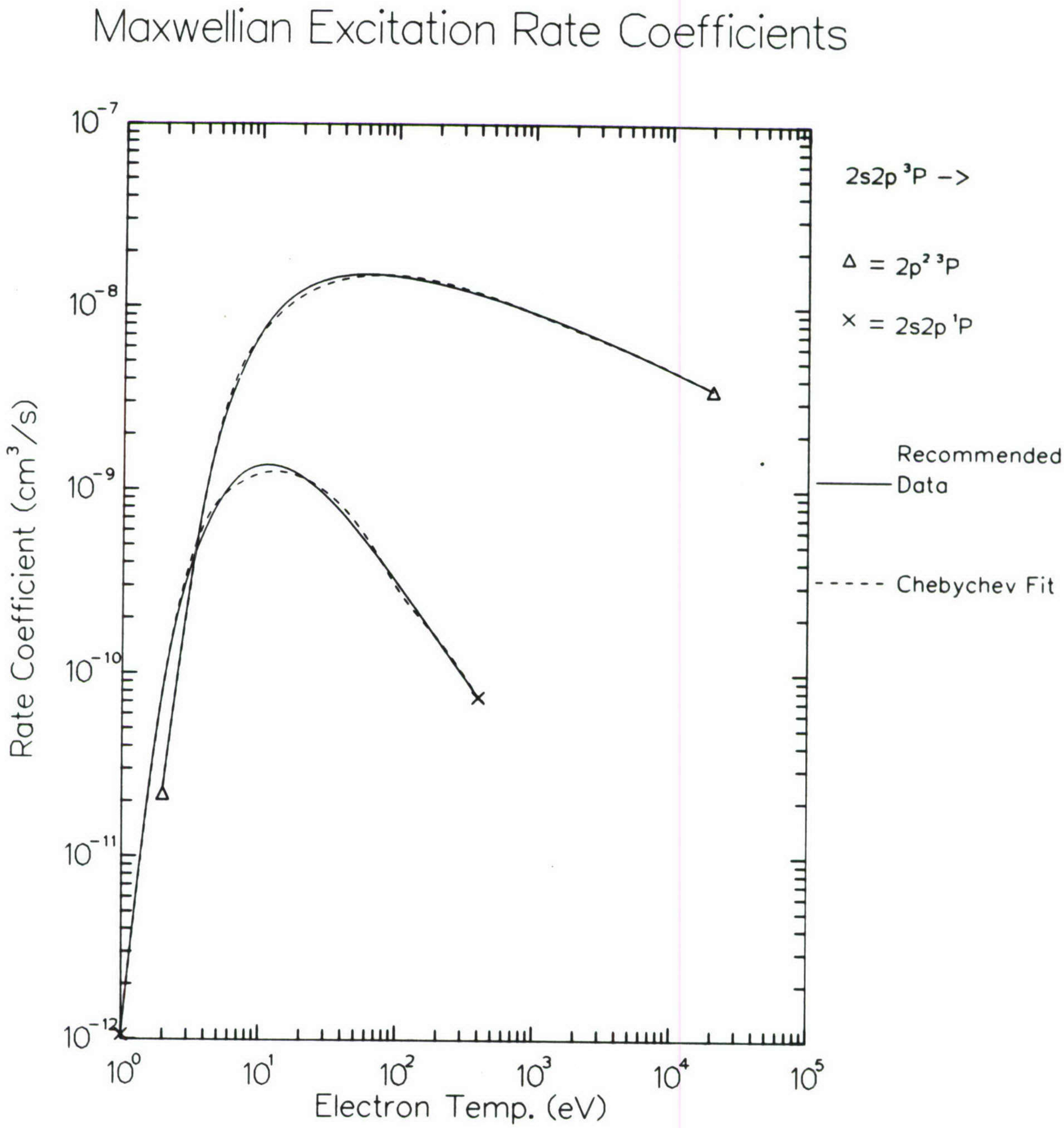
Notes: The recommended excitation-rate data for O^{4+} from the compilation [T.77] were based on close-coupling [T.85, T.86, T.106, T.107], Coulomb-Born-Exchange, and distorted-wave [T.79, T.80] calculations. This work has been updated to take into account recent multi-term close-coupling calculations [T.108] which have been recommended in compilation [T.78].

Chebychev Fitting Parameters for Rate Coefficients

E_{min} (eV)	E_{max} (eV)	C1	C2	C3	C4	C5	C6	C7
(2s2p ^3P - $2p^2$ ^3P)								
2.0	2.0E+04	1.30588E-08	1.03053E-09	-6.27763E-09	1.88702E-09	1.17150E-09	-1.18126E-09	3.34989E-10
(2s2p ^3P - 2s2p ^1P)								
1.0	4.0E+02	7.97039E-10	1.86576E-12	-5.44841E-10	1.50559E-10	2.02182E-10	-1.15445E-10	-1.78239E-11

See appendix for Chebychev fit details.

$e^- + O^{4+}$ (Be-like)


Maxwellian Excitation Rate Coefficients
10^{-7}
10^{-8}
10^{-9}
10^{-10}
10^{-11}
10^{-12}
Rate Coefficient (cm^3/s)
10^0
10^1
10^2
10^3
10^4
10^5
Electron Temp. (eV)
$2s2p\ ^3P$ ->
Δ = $2p^2\ ^3P$
× = $2s2p\ ^1P$
Recommended Data
Chebychev Fit

Electron-Impact Excitation Rate Coefficients for $e^- + O^{4+}$ (Be-like)

Maxwellian Rate Coefficients (cm^3/s)

e^- Temp. (eV)	$2s2p\ ^3P - 2p^2\ ^1D$ (E_{th} = 18.5 eV)	$2s2p\ ^3P - 2p^2\ ^1S$ (E_{th} = 25.5 eV)
2.0E+00	2.65E-13	
4.0E+00	1.89E-11	3.70E-13
7.0E+00	1.01E-10	4.13E-12
1.0E+01	1.82E-10	9.94E-12
2.0E+01	2.96E-10	2.26E-11
4.0E+01	2.89E-10	2.56E-11
7.0E+01	2.29E-10	2.11E-11
1.0E+02	1.86E-10	1.70E-11
2.0E+02	1.15E-10	9.58E-12
4.0E+02	6.74E-11	4.62E-12
7.0E+02	4.37E-11	2.30E-12
1.0E+03	3.33E-11	1.39E-12
Accuracy:	50%	50%

References: T.77, T.78, T.79, T.85, T.86, T.106, T.107, T.108

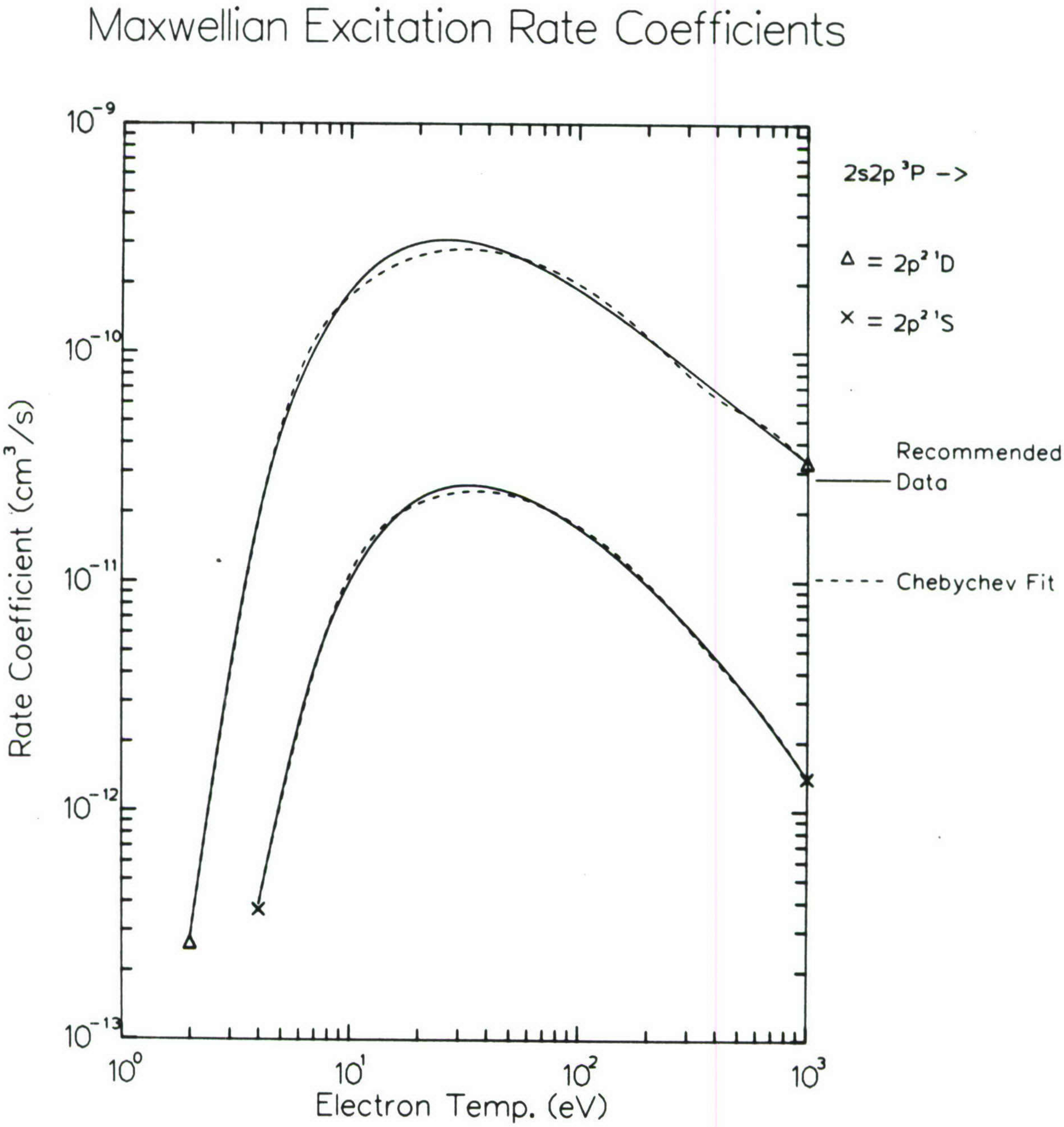
Notes: The recommended excitation-rate data for O^{4+} from the compilation [T.77] were based on close-coupling [T.85, T.86, T.106, T.107], Coulomb-Born-Exchange, and distorted-wave [T.79, T.80] calculations. This work has been updated to take into account recent multi-term close-coupling calculations [T.108] which have been recommended in compilation [T.78].

Chebychev Fitting Parameters for Rate Coefficients

E_{min} (eV)	E_{max} (eV)	C1	C2	C3	C4	C5	C6	C7
($2s2p\ ^3P - 2p^2\ ^1D$)								
2.0	1.0E+03	2.00614E-10	1.24317E-11	-1.24310E-10	2.34308E-11	4.32401E-11	-1.95254E-11	-2.63482E-12
($2s2p\ ^3P - 2p^2\ ^1S$)								
4.0	1.0E+03	1.76663E-11	-1.37469E-12	-1.08166E-11	3.85721E-12	2.57191E-12	-1.97331E-12	2.90607E-13

See appendix for Chebychev fit details.

$e^- + O^{4+}$ (Be-like)



Maxwellian Excitation Rate Coefficients
10^-9
10^-10
10^-11
10^-12
10^-13
10^0
10^1
10^2
10^3
Rate Coefficient (cm^3/s)
Electron Temp. (eV)
2s2p ³P ->
Δ = 2p² ¹D
× = 2p² ¹S
Recommended Data
Chebychev Fit

Electron-Impact Excitation Rate Coefficients for
$e^- + O^{4+}$ (Be-like)

Maxwellian Rate Coefficients (cm^3/s)

e^- Temp. (eV)	2s2p ^1P - $2p^2$ ^1D (E_{th} = 9.04 eV)	2s2p ^1P - $2p^2$ ^1S (E_{th} = 16.0 eV)	2s2p ^1P - $2p^2$ ^3P (E_{th} = 6.82 eV)
1.0E+00	2.28E-11		2.53E-11
2.0E+00	1.52E-09	1.51E-11	4.90E-10
4.0E+00	1.06E-08	5.94E-10	1.60E-09
7.0E+00	2.20E-08	2.57E-09	2.09E-09
1.0E+01	2.80E-08	4.39E-09	2.02E-09
2.0E+01	3.34E-08	7.52E-09	1.51E-09
4.0E+01	3.27E-08	8.96E-09	9.28E-10
7.0E+01	2.99E-08	9.06E-09	5.22E-10
1.0E+02	2.77E-08	8.80E-09	3.48E-10
2.0E+02	2.34E-08	7.92E-09	
4.0E+02	1.94E-08	6.82E-09	
7.0E+02	1.64E-08	5.91E-09	
1.0E+03	1.47E-08	5.36E-09	
2.0E+03	1.17E-08	4.35E-09	
4.0E+03	9.27E-09	3.48E-09	
7.0E+03	7.61E-09	2.87E-09	
1.0E+04	6.68E-09	2.54E-09	
2.0E+04	5.17E-09	1.97E-09	
Accuracy:	50%	50%	50%

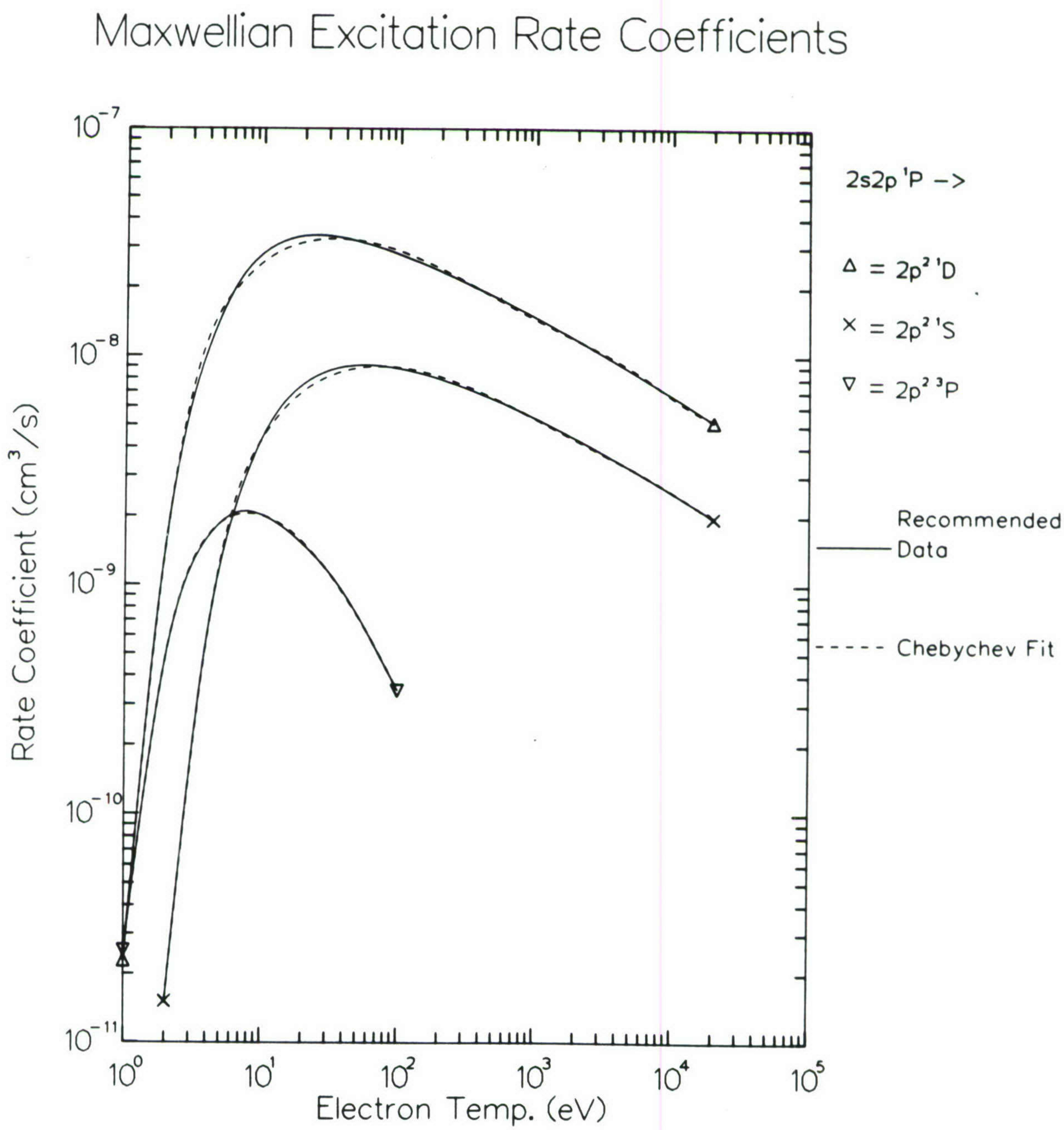
References: T.77, T.78, T.79, T.85, T.86, T.106, T.107, T.108

Notes: The recommended excitation-rate data for O^{4+} from the compilation [T.77] were based on close-coupling [T.85, T.86, T.106, T.107], Coulomb-Born-Exchange, and distorted-wave [T.79, T.80] calculations. This work has been updated to take into account recent multi-term close-coupling calculations [T.108] which have been recommended in compilation [T.78].

Chebychev Fitting Parameters for Rate Coefficients

E_{min} (eV)	E_{max} (eV)	C1	C2	C3	C4	C5	C6	C7
(2s2p ^1P - $2p^2$ ^1D)								
1.0	2.0E+04	2.55139E-08	-1.39091E-10	-1.33162E-08	5.92441E-09	1.78247E-09	-3.20571E-09	1.37916E-09
(2s2p ^1P - $2p^2$ ^1S)								
2.0	2.0E+04	7.75648E-09	4.82306E-10	-3.79019E-09	1.23389E-09	6.82644E-10	-7.38793E-10	2.21833E-10
(2s2p ^1P - $2p^2$ ^3P)								
1.0	1.0E+02	1.69282E-09	1.76864E-10	-9.32080E-10	1.10492E-10	2.53300E-10	-1.26160E-10	1.88643E-11

$e^- + O^{4+}$ (Be-like)


Maxwellian Excitation Rate Coefficients
Rate Coefficient (cm³/s)
Electron Temp. (eV)
10⁻⁷
10⁻⁸
10⁻⁹
10⁻¹⁰
10⁻¹¹
10⁰
10¹
10²
10³
10⁴
10⁵
2s2p ¹P ->
Δ = 2p² ¹D
× = 2p² ¹S
∇ = 2p² ³P
Recommended Data
Chebychev Fit

Electron-Impact Excitation Rate Coefficients for $e^- + O^{4+}$ (Be-like)

Maxwellian Rate Coefficients (cm^3/s)

e^- Temp. (eV)	$2p^2\ ^3P - 2p^2\ ^1D$ (E_{th} = 2.22 eV)	$2p^2\ ^3P - 2p^2\ ^1S$ (E_{th} = 9.18 eV)	$2p^2\ ^1D - 2p^2\ ^1S$ (E_{th} = 6.96 eV)
1.0E+00		1.72E-13	4.44E-12
2.0E+00		1.18E-11	1.03E-10
4.0E+00	4.24E-09	7.97E-11	4.19E-10
7.0E+00	3.87E-09	1.54E-10	6.76E-10
1.0E+01	3.40E-09	1.82E-10	7.70E-10
2.0E+01	2.41E-09	1.79E-10	7.89E-10
4.0E+01	1.52E-09	1.33E-10	6.80E-10
7.0E+01	9.19E-10	9.24E-11	5.64E-10
1.0E+02	6.73E-10	7.07E-11	4.92E-10
2.0E+02		4.02E-11	3.66E-10
4.0E+02		2.23E-11	2.67E-10
7.0E+02		1.40E-11	2.05E-10
1.0E+03		1.06E-11	1.72E-10
Accuracy:	50%	50%	50%

References: T.77, T.78, T.79, T.85, T.86, T.106, T.107, T.108

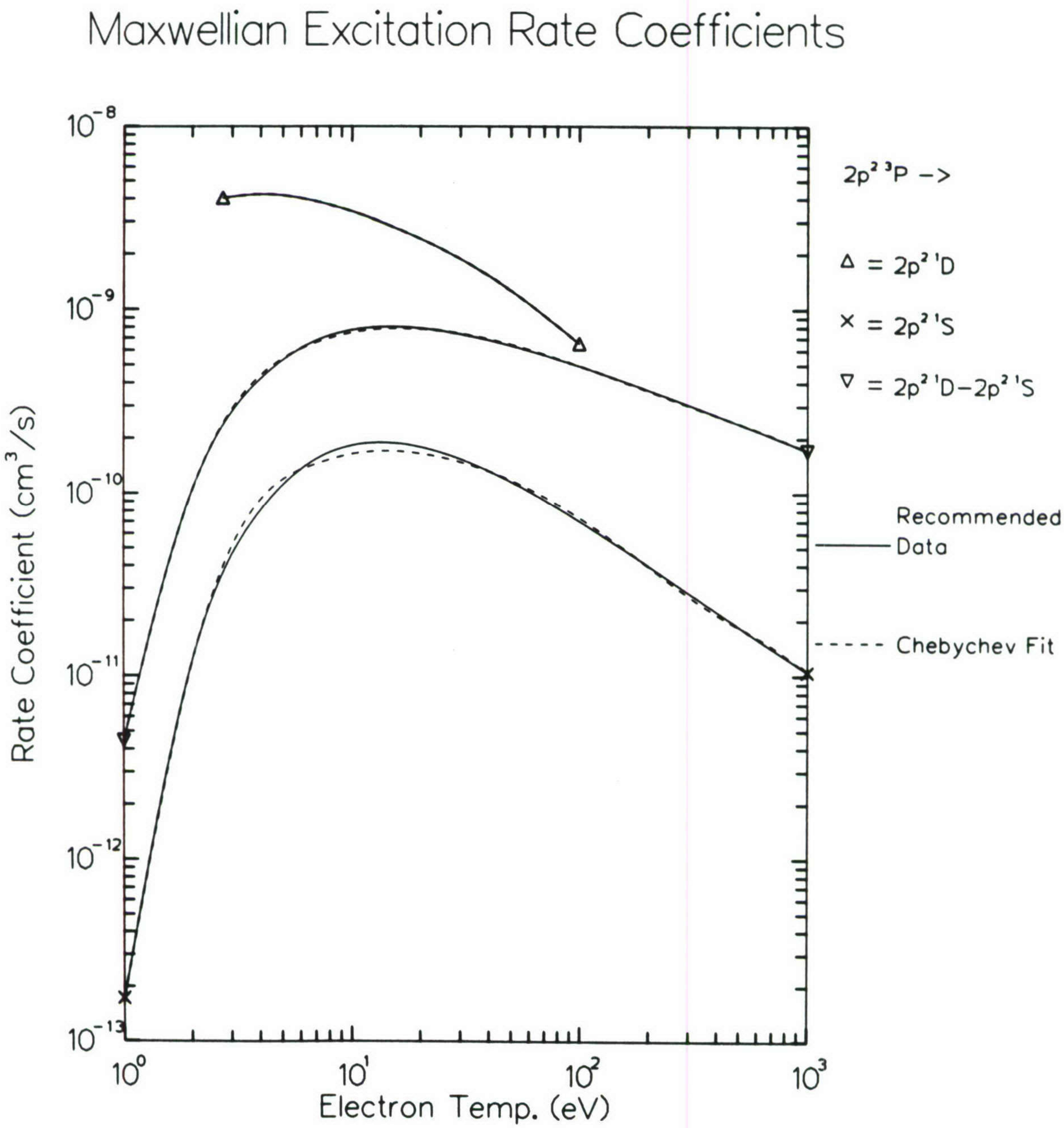
Notes: The recommended excitation-rate data for O^{4+} from the compilation [T.77] were based on close-coupling [T.85, T.86, T.106, T.107], Coulomb-Born-Exchange, and distorted-wave [T.79, T.80] calculations. This work has been updated to take into account recent multi-term close-coupling calculations [T.108] which have been recommended in compilation [T.78].

Chebychev Fitting Parameters for Rate Coefficients

E_{min} (eV)	E_{max} (eV)	C1	C2	C3	C4	C5	C6	C7
($2p^2\ ^3P - 2p^2\ ^1D$)								
2.7	1.1E+02	5.09416E-09	-1.97248E-09	-1.47949E-10	2.54123E-10	-6.31244E-11	2.38540E-11	9.495304-12
($2p^2\ ^3P - 2p^2\ ^1S$)								
1.0	1.0E+03	1.10657E-10	-5.71417E-12	-7.39125E-11	2.91795E-11	2.03464E-11	-1.83167E-11	3.55854E-12
($2p^2\ ^1D - 2p^2\ ^1S$)								
1.0	1.0E+03	6.73949E-10	5.10034E-11	-3.35844E-10	9.54979E-11	7.23932E-11	-6.28004E-11	1.46132E-11

See appendix for Chebychev fit details.

$e^- + O^{4+}$ (Be-like)


Maxwellian Excitation Rate Coefficients
Rate Coefficient (cm³/s)
Electron Temp. (eV)
2p² ³P ->
Δ = 2p² ¹D
× = 2p² ¹S
∇ = 2p² ¹D-2p² ¹S
Recommended Data
Chebychev Fit

Electron-Impact Excitation Rate Coefficients for $e^- + O^{5+}$ (Li-like)

Maxwellian Rate Coefficients (cm^3/s)

e^- Temp. (eV)	$2s\ ^2S - 2p\ ^2P$ (E_{th} = 12.0 eV)	$2s\ ^2S - 3s\ ^2S$ (E_{th} = 79.4 eV)
2.0E+00	3.76E-10	
4.0E+00	5.39E-09	
7.0E+00	1.50E-08	
1.0E+01	2.13E-08	1.13E-12
2.0E+01	2.89E-08	3.95E-11
4.0E+01	2.98E-08	1.94E-10
7.0E+01	2.77E-08	3.36E-10
1.0E+02	2.59E-08	3.93E-10
2.0E+02	2.20E-08	4.15E-10
4.0E+02	1.82E-08	3.63E-10
7.0E+02	1.54E-08	3.03E-10
1.0E+03	1.38E-08	2.65E-10
2.0E+03	1.11E-08	1.98E-10
4.0E+03	8.74E-09	1.45E-10
7.0E+03	7.17E-09	1.11E-10
1.0E+04	6.30E-09	9.34E-11
2.0E+04	4.88E-09	6.66E-11
Accuracy:	10%	50%

References: T.77, T.79, T.87, T.89, T.109

Notes: The recommended excitation-rate data form O^{5+} from the compilation [T.77] were based on close-coupling [T.87, T.89, T.109,] and distorted-wave [T.79, T.80] calculations. Recent 9-term distorted-wave calculations [T.110] confirm these recommended data.

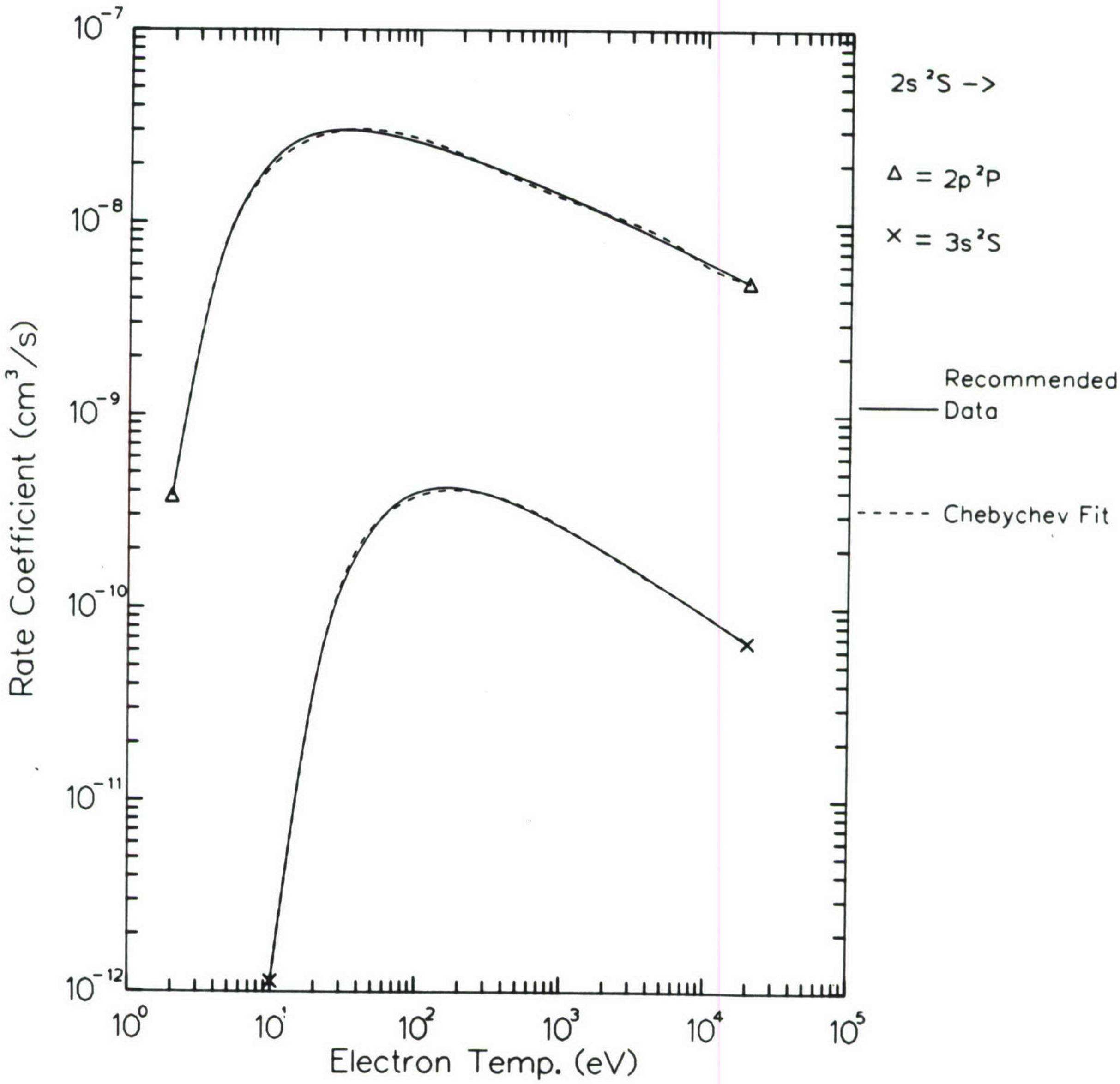
Chebychev Fitting Parameters for Rate Coefficients

E_{min} (eV)	E_{max} (eV)	C1	C2	C3	C4	C5	C6	C7
($2s\ ^2S - 2p\ ^2S$)								
2.0	2.0E+04	2.47750E-08	-1.63420E-09	-1.13883E-08	6.30879E-09	1.53860E-10	-2.40177E-09	1.49543E-09
($2s\ ^2S - 3s\ ^2S$)								
10.	2.0E+04	3.21408E-10	7.91347E-12	-1.72339E-10	6.24336E-11	3.45652E-11	-3.76575E-11	1.08934E-11

See appendix for Chebychev fit details.

$e^- + O^{5+}$ (Li-like)

Maxwellian Excitation Rate Coefficients



Electron-Impact Excitation Rate Coefficients for $e^- + O^{5+}$ (Li-like)

Maxwellian Rate Coefficients (cm^3/s)

e^- Temp. (eV)	$2s\ ^2S - 3p\ ^2P$ (E_{th} = 82.6 eV)	$2s\ ^2S - 3d\ ^2D$ (E_{th} = 83.6 eV)
1.0E+01	4.84E-13	9.91E-13
2.0E+01	2.05E-11	4.72E-11
4.0E+01	1.18E-10	2.85E-10
7.0E+01	2.35E-10	5.63E-10
1.0E+02	3.07E-10	7.09E-10
2.0E+02	4.26E-10	8.47E-10
4.0E+02	5.17E-10	8.17E-10
7.0E+02	5.67E-10	7.24E-10
1.0E+03	5.86E-10	6.52E-10
2.0E+03	5.92E-10	5.09E-10
4.0E+03	5.62E-10	3.82E-10
7.0E+03	5.20E-10	2.97E-10
1.0E+04	4.87E-10	2.52E-10
2.0E+04	4.19E-10	1.81E-10
Accuracy:	30%	50%

References: T.77, T.79, T.87, T.89, T.109

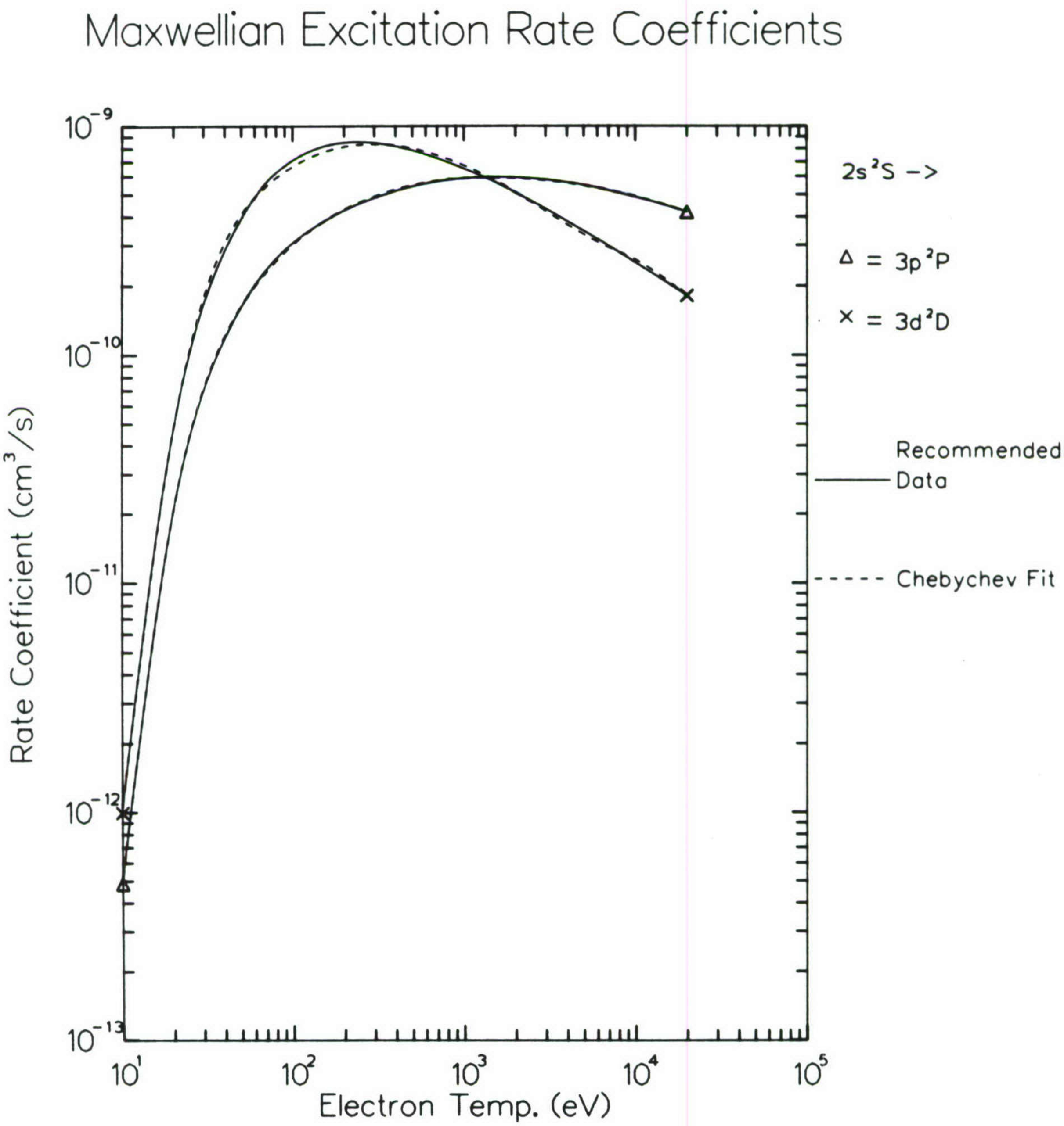
Notes: The recommended excitation-rate data form O^{5+} from the compilation [T.77] were based on close-coupling [T.87, T.89, T.109,] and distorted-wave [T.79, T.80] calculations. Recent 9-term distorted-wave calculations [T.110] confirm these recommended data.

Chebychev Fitting Parameters for Rate Coefficients

E_{min} (eV)	E_{max} (eV)	C1	C2	C3	C4	C5	C6	C7
($2s\ ^2S - 3p\ ^2P$)								
10.	2.0E+04	6.72489E-10	2.63694E-10	-1.61156E-10	-4.80486E-11	3.63901E-11	-6.72744E-12	-2.07708E-12
($2s\ ^2S - 3d\ ^2D$)								
10.	2.0E+04	6.98512E-10	8.22590E-11	-3.57244E-10	6.34302E-11	1.02397E-10	-5.59160E-11	-3.64502E-12

See appendix for Chebychev fit details.

$e^- + O^{5+}$ (Li-like)



Maxwellian Excitation Rate Coefficients
2s²S ->
Δ = 3p²P
× = 3d²D
Recommended Data
Chebychev Fit
Rate Coefficient (cm³/s)
Electron Temp. (eV)
10⁻⁹
10⁻¹⁰
10⁻¹¹
10⁻¹²
10⁻¹³
10¹
10²
10³
10⁴
10⁵

Electron-Impact Excitation Rate Coefficients for $e^- + O^{6+}$ (He-like)

Maxwellian Rate Coefficients (cm^3/s)

e^- Temp. (eV)	$1s^2\ ^1S - 1s2p\ ^3P$ (E_{th} = 568.6 eV)	$1s^2\ ^1S - 1s2s\ ^3S$ (E_{th} = 561.0 eV)
7.0E+01	5.82E-14	2.46E-14
1.0E+02	5.18E-13	1.94E-13
2.0E+02	5.22E-12	1.64E-12
4.0E+02	1.18E-11	3.32E-12
7.0E+02	1.25E-11	3.38E-12
1.0E+03	1.09E-11	2.91E-12
2.0E+03	6.46E-12	1.74E-12
4.0E+03	3.12E-12	8.57E-13
7.0E+03	1.58E-12	4.42E-13
1.0E+04	9.99E-13	2.81E-13
2.0E+04	3.97E-13	1.10E-13
Accuracy:	20%	20%

References: T.77, T.78, T.79, T.80, T.90, T.91, T.111, T.112, T.113

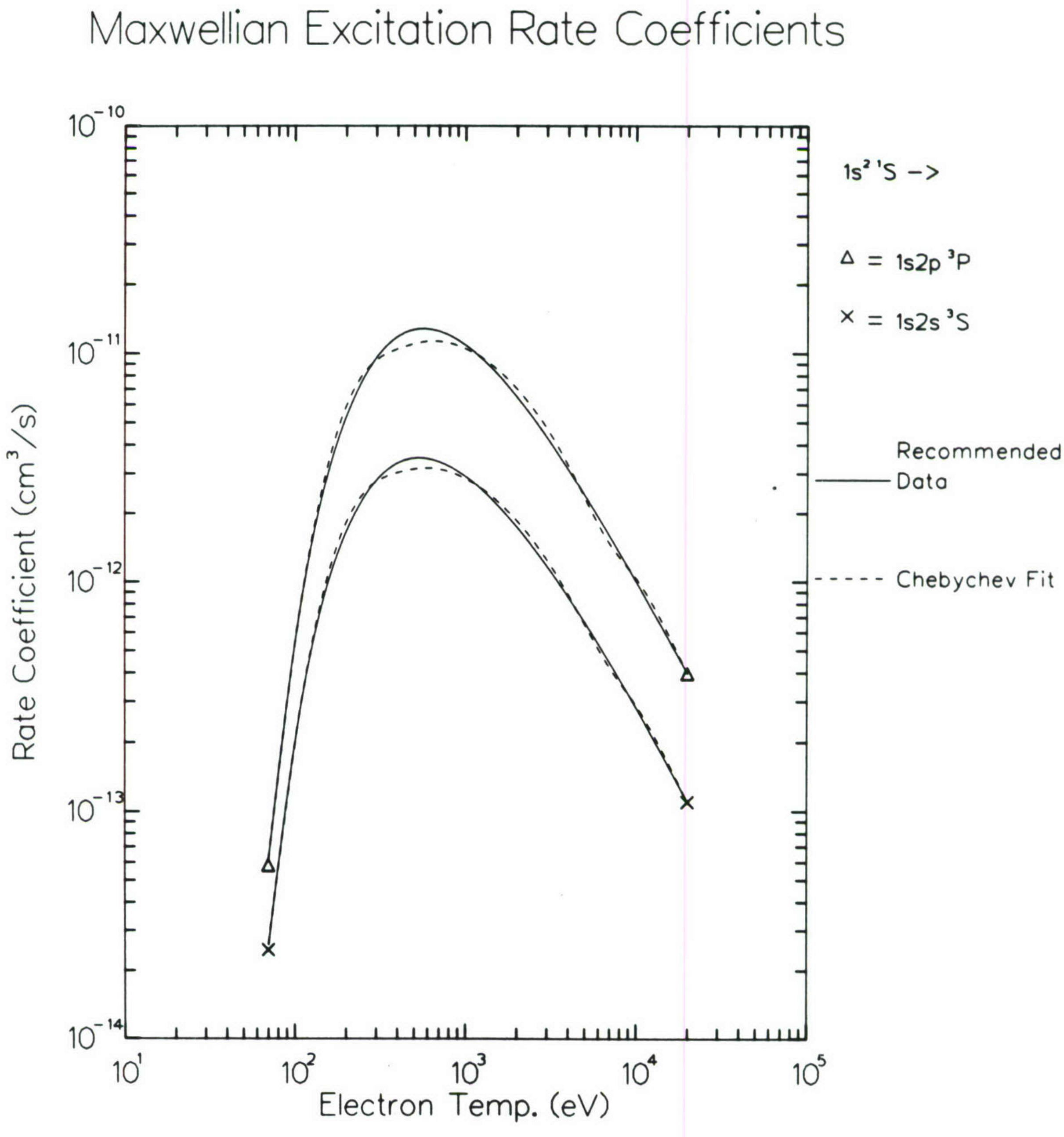
Notes: The recommended excitation-rate data for O^{6+} from the compilation [T.77] were based on close-coupling [T.111] and distorted-wave [T.79, T.80, T.90, T.91, T.112] calculations. This work has been updated to take into account more recent 11-term close-coupling calculations [T.113] which have been recommended in compilation [T.78].

Chebychev Fitting Parameters for Rate Coefficients

E_{min} (eV)	E_{max} (eV)	C1	C2	C3	C4	C5	C6	C7
($1s^2\ ^1S - 1s2p\ ^3P$)								
70.	2.0E+04	7.54436E-12	-8.99367E-13	-4.78823E-12	2.11735E-12	1.23713E-12	-1.04866E-12	6.51101E-15
($1s^2\ ^1S - 1s2s\ ^3S$)								
70.	2.0E+04	2.13867E-12	-3.02818E-13	-1.32490E-12	6.46308E-13	2.84622E-13	-3.00858E-13	3.82309E-14

See appendix for Chebychev fit details.

$e^- + O^{6+}$ (He-like)


Maxwellian Excitation Rate Coefficients
10^{-10}
10^{-11}
10^{-12}
10^{-13}
10^{-14}
Rate Coefficient (cm^3/s)
10^1
10^2
10^3
10^4
10^5
Electron Temp. (eV)
$1s^2\,{}^1S$ ->
Δ = $1s2p\,{}^3P$
× = $1s2s\,{}^3S$
Recommended Data
Chebychev Fit

Electron-Impact Excitation Rate Coefficients for $e^- + O^{6+}$ (He-like)

Maxwellian Rate Coefficients (cm^3/s)

e^- Temp. (eV)	$1s^2\ ^1S - 1s2p\ ^1P$ (E_{th} = 573.9 eV)	$1s^2\ ^1S - 1s2s\ ^1S$ (E_{th} = 568.7 eV)
7.0E+01	6.59E-14	2.49E-14
1.0E+02	6.95E-13	2.30E-13
2.0E+02	1.06E-11	2.76E-12
4.0E+02	4.16E-11	8.44E-12
7.0E+02	7.54E-11	1.25E-11
1.0E+03	9.60E-11	1.41E-11
2.0E+03	1.26E-10	1.48E-11
4.0E+03	1.41E-10	1.34E-11
7.0E+03	1.42E-10	1.16E-11
1.0E+04	1.39E-10	1.03E-11
2.0E+04	1.27E-10	7.96E-12
Accuracy:	10%	20%

References: T.77, T.78, T.79, T.80, T.90, T.91, T.111, T.112, T.113

Notes: The recommended excitation-rate data for O^{6+} from the compilation [T.77] were based on close-coupling [T.111] and distorted-wave [T.79, T.80, T.90, T.91, T.112] calculations. This work has been updated to take into account more recent 11-term close-coupling calculations [T.113] which have been recommended in compilation [T.78].

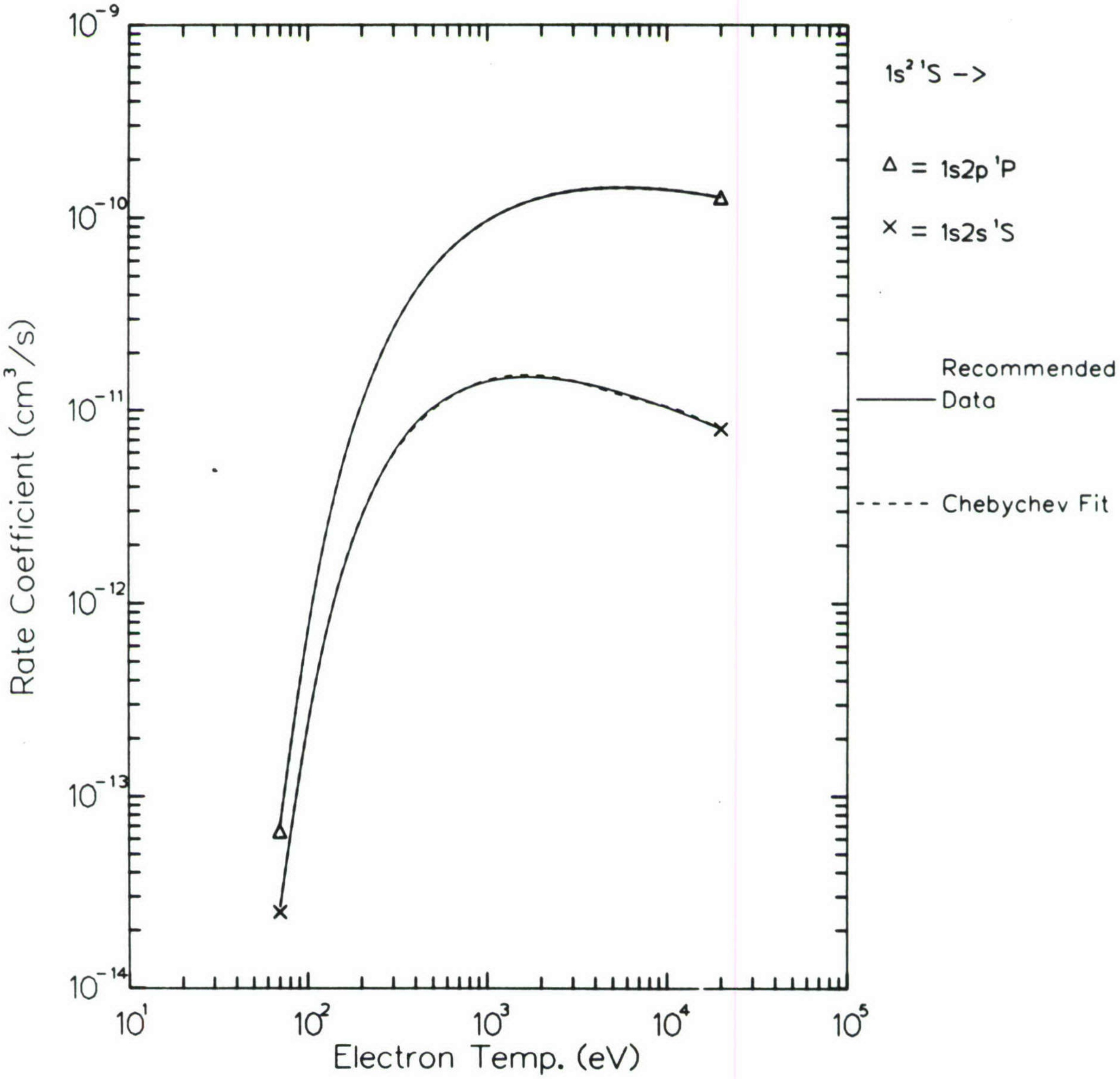
Chebychev Fitting Párameters for Rate Coefficients

E_{min} (eV)	E_{max} (eV)	C1	C2	C3	C4	C5	C6	C7
($1s^2\ ^1S - 1s2p\ ^1P$)								
70.	2.0E+04	1.56962E-10	7.95537E-11	-1.88229E-11	-1.79162E-11	5.74164E-12	1.90131E-12	-1.79506E-12
($1s^2\ ^1S - 1s2s\ ^1S$)								
70.	2.0E+04	1.56086E-11	5.24378E-12	-4.95170E-12	-1.04753E-12	1.61492E-12	-2.36367E-13	-4.82762E-13

See appendix for Chebychev fit details.

$e^- + O^{6+}$ (He-like)

Maxwellian Excitation Rate Coefficients



Electron-Impact Excitation Rate Coefficients for
$e^- + O^{6+}$ (He-like)

Maxwellian Rate Coefficients (cm^3/s)

e^- Temp. (eV)	1s2s ^3S - 1s2p ^3P (E_{th} = 7.58 eV)	1s2s ^3S - 1s2s ^1S (E_{th} = 7.77 eV)	1s2s ^3S - 1s2p ^1P (E_{th} = 13.0 eV)
1.0E+00	1.58E-10	8.12E-13	
2.0E+00	4.63E-09	2.60E-11	2.27E-12
4.0E+00	2.02E-08	1.16E-10	3.20E-11
7.0E+00	3.24E-08	1.91E-10	1.13E-10
1.0E+01	3.64E-08	2.26E-10	1.83E-10
2.0E+01	3.66E-08	2.56E-10	3.16E-10
4.0E+01	3.22E-08	2.39E-10	3.54E-10
7.0E+01	2.80E-08	1.87E-10	2.88E-10
1.0E+02	2.54E-08	1.52E-10	2.28E-10
2.0E+02	2.08E-08	7.92E-11	1.25E-10
4.0E+02	1.69E-08	3.77E-11	5.80E-11
7.0E+02	1.42E-08	1.95E-11	2.78E-11
1.0E+03	1.26E-08		1.71E-11
2.0E+03	9.97E-09		
4.0E+03	7.81E-09		
7.0E+03	6.37E-09		
1.0E+04	5.58E-09		
2.0E+04	4.29E-09		
Accuracy:	50%	50%	50%

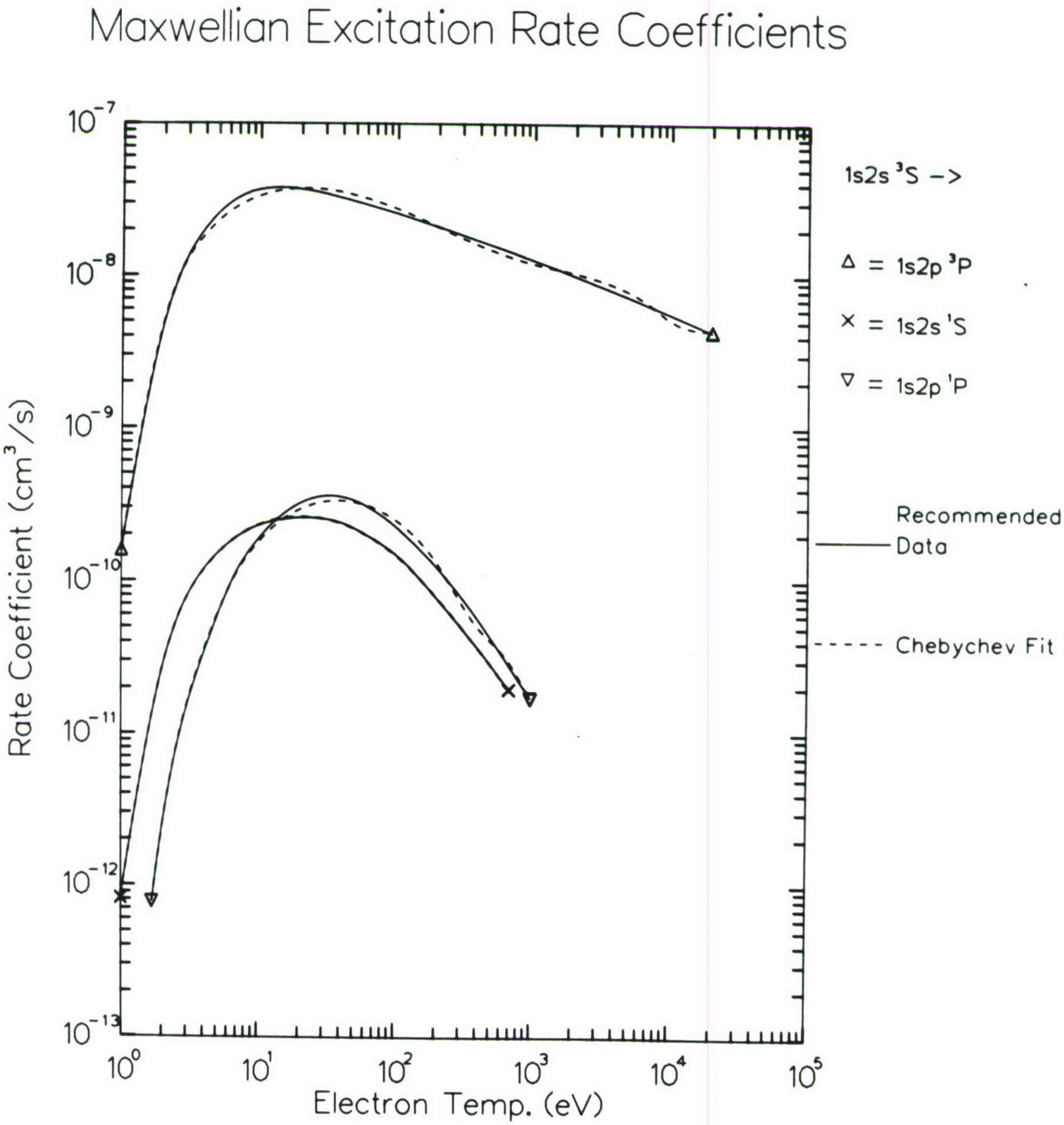
References: T.77, T.78, T.79, T.80, T.90, T.91, T.111, T.112, T.113

Notes: The recommended excitation-rate data for O^{6+} from the compilation [T.77] were based on close-coupling [T.111] and distorted-wave [T.79, T.80, T.90, T.91, T.112] calculations. This work has been updated to take into account more recent 11-term close-coupling calculations [T.113] which have been recommended in compilation [T.78].

Chebychev Fitting Parameters for Rate Coefficients

E_{min} (eV)	E_{max} (eV)	C1	C2	C3	C4	C5	C6	C7
(1s2s ^3S - 1s2p ^3P)								
1.0	2.0E+04	2.70182E-08	-3.10854E-09	-1.32560E-08	8.70969E-09	-3.99140E-10	-3.49128E-09	2.41354E-09
(1s2s ^3S - 1s2s ^1S)								
1.0	7.0E+02	1.90883E-10	5.32812E-12	-1.20258E-10	1.45335E-11	3.81064E-11	-1.05133E-11	-3.12953E-12
(1s2s ^3S - 1s2p ^1P)								
1.7	1.0E+03	2.17380E-10	7.90830E-12	-1.47047E-10	6.04908E-12	6.16973E-11	-5.90411E-12	-1.45140E-11

$e^- + O^{6+}$ (He-like)



Maxwellian Excitation Rate Coefficients
Rate Coefficient (cm³/s)
Electron Temp. (eV)
10⁻⁷
10⁻⁸
10⁻⁹
10⁻¹⁰
10⁻¹¹
10⁻¹²
10⁻¹³
10⁰
10¹
10²
10³
10⁴
10⁵
1s2s ³S ->
Δ = 1s2p ³P
× = 1s2s ¹S
∇ = 1s2p ¹P
Recommended Data
Chebychev Fit

Electron-Impact Excitation Rate Coefficients for $e^- + O^{6+}$ (He-like)

Maxwellian Rate Coefficients (cm^3/s)

e^- Temp. (eV)	$1s2s\ ^1S - 1s2p\ ^1P$ (E_{th} = 5.19 eV)	$1s2p\ ^3P - 1s2p\ ^1P$ (E_{th} = 5.38 eV)
1.0E+00	1.17E-09	1.95E-11
2.0E+00	1.13E-08	1.81E-10
4.0E+00	3.00E-08	4.76E-10
7.0E+00	4.06E-08	6.74E-10
1.0E+01	4.33E-08	7.36E-10
2.0E+01	4.19E-08	7.26E-10
4.0E+01	3.66E-08	5.71E-10
7.0E+01	3.17E-08	4.28E-10
1.0E+02	2.88E-08	3.34E-10
2.0E+02	2.35E-08	1.74E-10
4.0E+02	1.90E-08	8.41E-11
7.0E+02	1.59E-08	4.15E-11
1.0E+03	1.41E-08	2.56E-11
Accuracy:	50%	50%

References: T.77, T.78, T.79, T.80, T.90, T.91, T.111, T.112, T.113

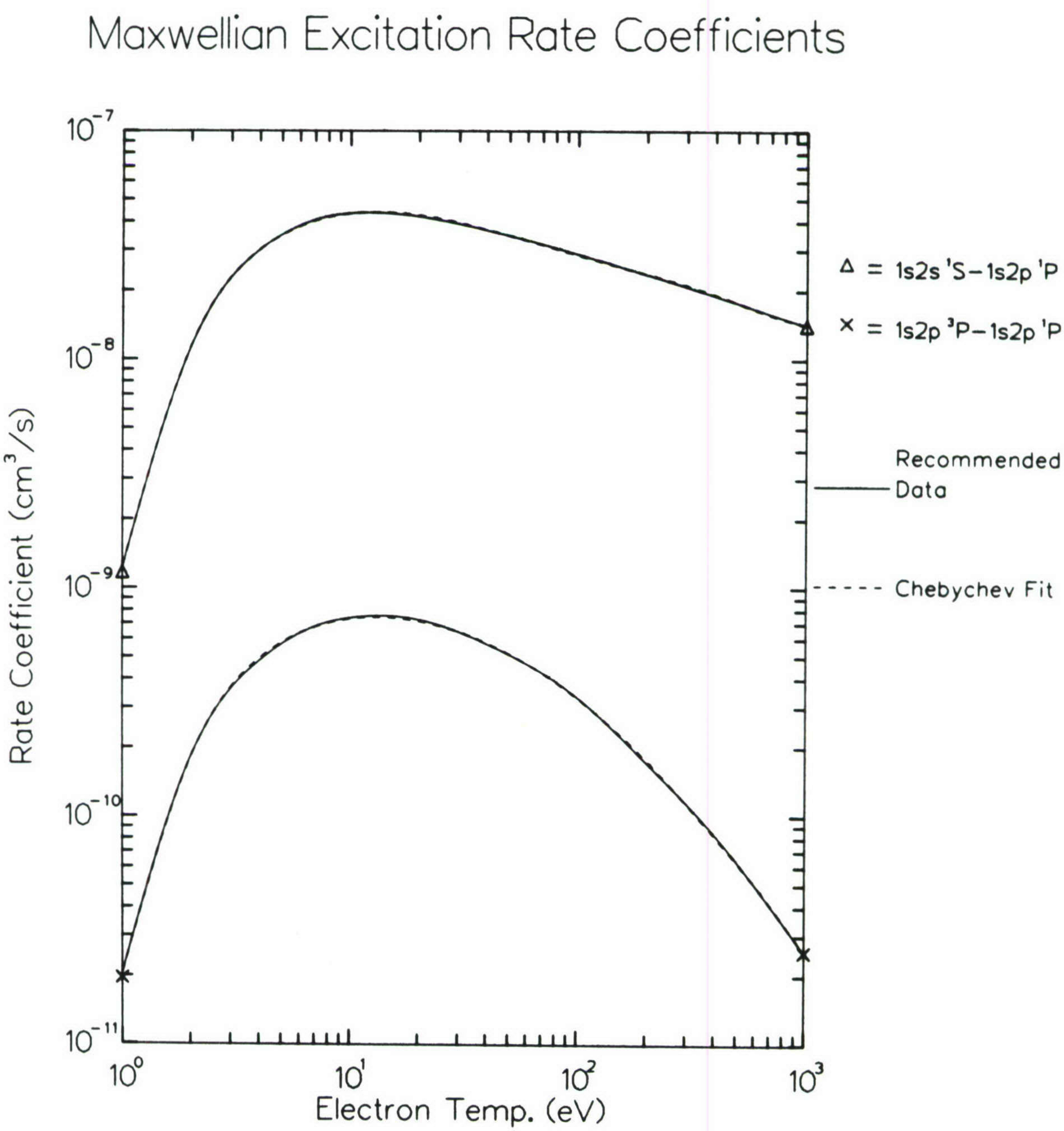
Notes: The recommended excitation-rate data for O^{6+} from the compilation [T.77] were based on close-coupling [T.111] and distorted-wave [T.79, T.80, T.90, T.91, T.112] calculations. This work has been updated to take into account more recent 11-term close-coupling calculations [T.113] which have been recommended in compilation [T.78].

Chebychev Fitting Parameters for Rate Coefficients

E_{min} (eV)	E_{max} (eV)	C1	C2	C3	C4	C5	C6	C7
($1s2s\ ^1S - 1s2p\ ^1P$)								
1.0	1.0E+03	4.33355E-08	3.11961E-09	-1.70031E-08	6.37404E-09	1.68608E-09	-2.99923E-09	1.31096E-09
($1s2p\ ^3P - 1s2p\ ^1P$)								
1.0	1.0E+03	5.35253E-10	-8.00935E-11	-3.15471E-10	1.38127E-10	5.99210E-11	-5.50070E-11	1.04530E-11

See appendix for Chebychev fit details.

$e^- + O^{6+}$ (He-like)


Maxwellian Excitation Rate Coefficients
Rate Coefficient (cm³/s)
Electron Temp. (eV)
10⁻⁷
10⁻⁸
10⁻⁹
10⁻¹⁰
10⁻¹¹
10⁰
10¹
10²
10³
Δ = 1s2s ¹S–1s2p ¹P
× = 1s2p ³P–1s2p ¹P
Recommended Data
Chebychev Fit

Electron-Impact Excitation Rate Coefficients for
$e^- + O^{7+}$ (H-like)

Maxwellian Rate Coefficients (cm^3/s)

e^- Temp. (eV)	1s-2p (E_{th} = 653.6 eV)	1s-2s (E_{th} = 653.5 eV)
4.0E+01		1.31E-14
7.0E+01	2.02E-14	4.86E-13
1.0E+02	2.80E-13	1.91E-12
2.0E+02	5.47E-12	8.14E-12
4.0E+02	2.23E-11	1.44E-11
7.0E+02	3.96E-11	1.66E-11
1.0E+03	4.96E-11	1.69E-11
2.0E+03	6.34E-11	1.55E-11
4.0E+03	6.92E-11	1.30E-11
7.0E+03	6.90E-11	1.08E-11
1.0E+04	6.71E-11	9.42E-12
2.0E+04	6.09E-11	7.07E-12
Accuracy:	10%	10%

References: T.77, T.93

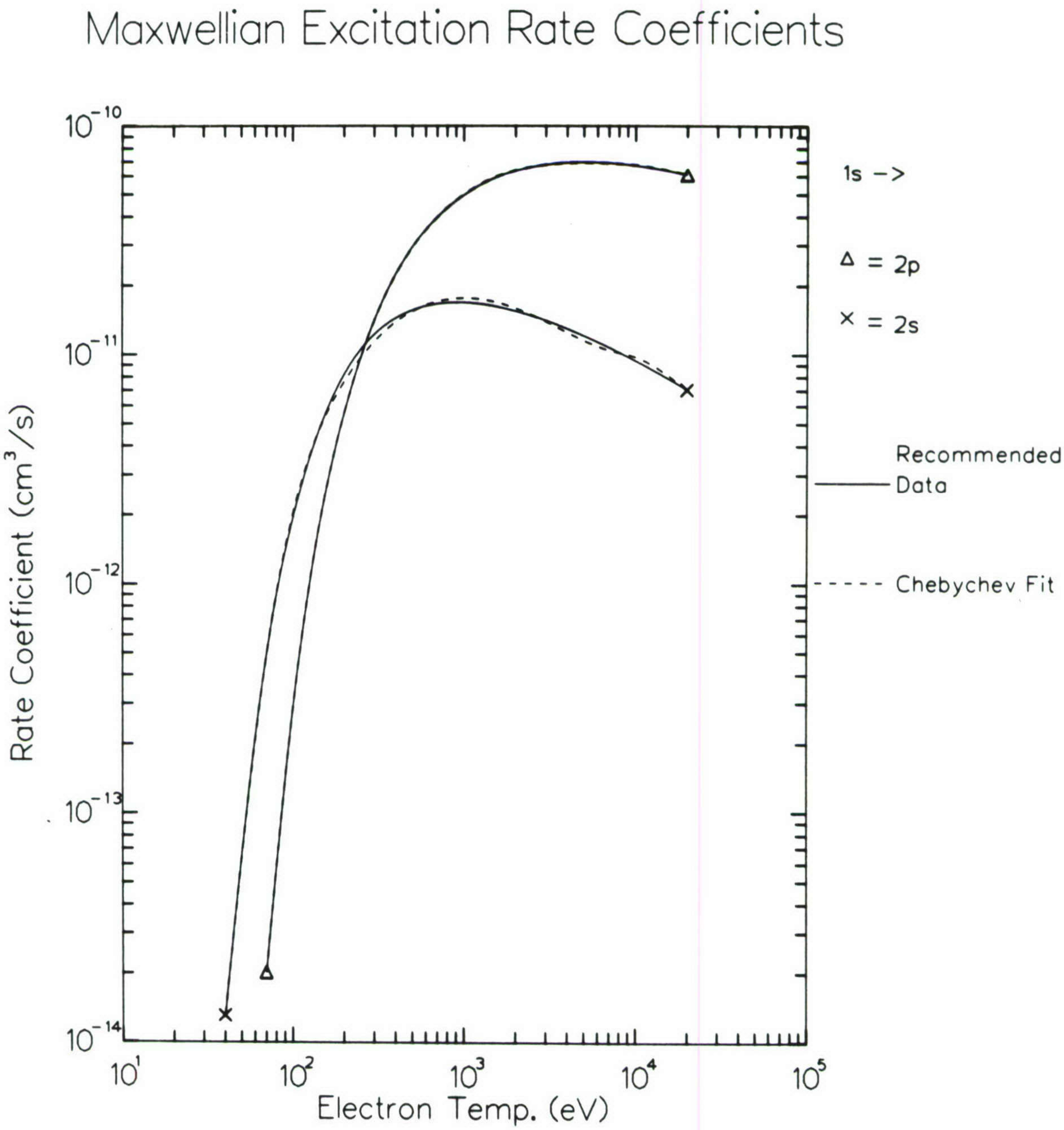
Notes: The recommended excitation-rate data for O^{7+} are from the compilation [T.77], and are based on pseudostate-augmented 3-term close-coupling and Coulomb-Born-Exchange calculations [T.93].

Chebychev Fitting Parameters for Rate Coefficients

E_{min} (eV)	E_{max} (eV)	C1	C2	C3	C4	C5	C6	C7
(1s-2p)								
70.	2.0E+04	7.75431E-11	3.83741E-11	-1.05330E-11	-8.52756E-12	3.45824E-12	5.61998E-13	-1.26809E-12
(1s-2s)								
40.	2.0E+04	1.65836E-11	4.64927E-12	-6.31928E-12	-5.68995E-13	2.23867E-12	-5.68786E-13	-6.86651E-13

See appendix for Chebychev fit details.

$e^- + O^{7+}$ (H-like)


Maxwellian Excitation Rate Coefficients
Rate Coefficient (cm³/s)
Electron Temp. (eV)
10⁻¹⁰
10⁻¹¹
10⁻¹²
10⁻¹³
10⁻¹⁴
10¹
10²
10³
10⁴
10⁵
1s ->
Δ = 2p
× = 2s
Recommended Data
Chebychev Fit

6. References

6.1 References to General Remarks (References G.1 – G.34) 6-1

6.2 References to Experiment (References E.1 – E.90) 6-5

6.3 References to Theory (References T.1 – T.114) 6-13

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Appendix

Calculation of Cross Sections and Rate Coefficients from Chebychev Fitting Parameters A-1

Sample FORTRAN Program A-4

Sample BASIC Program A-5

Calculation of Cross Sections and Rate Coefficients from Chebychev Fitting Parameters

For ease of numerical data retrieval, the method of least-squares fitting to the recommended cross sections and rate coefficients using the Chebychev (or Chebyshev) orthogonal polynomials has been used throughout this compilation. In general, it produced high accuracy fits to the recommended data. In a few cases, other means of fitting were consistently better than Chebychev, such as for electron-impact ionization cross sections, and were substituted.

The recommended cross-section data have been fitted to the following analytical expression

$$\sigma(E) = 1/2\ C_1 + \sum_{i=1}^{8} C_{i+1}\ T_i(X)$$

$$X = [(\ln E - \ln E_{min}) - (\ln E_{max} - \ln E)]/(\ln E_{max} - \ln E_{min})$$

where $T_i(X)$ are the Chebychev orthogonal polynomials. Similarly, the recommended rate coefficients have been fitted to the analytical expression

$$\alpha(T) = 1/2\ C_1 + \sum_{i=1}^{6} C_{i+1}\ T_i(X)$$

$$X = [(\ln T - \ln E_{min}) - (\ln E_{max} - \ln T)]/(\ln E_{max} - \ln E_{min})$$

The values of fitting parameters C_i, E_{min}, and E_{max} are given for each reaction after each cross-section or rate-coefficient table. In each case, the minimum number of parameters C_i are listed which are required to produce a satisfactory fit to the data. The cross section σ is given in units of cm^2, with collision energies E in units of eV/u. The rate coefficient α is in units of cm^3/s, with Maxwellian temperatures T in units of eV. (We follow the convention used frequently in plasma physics of expressing temperature in eV energy units, recognizing that kT is understood, where k is Boltzmann's constant.) The analytic representation of the cross section or rate coefficient should be used only in the region from E_{min} to E_{max}. The expressions for the Chebychev polynomials are reproduced below for convenience.

$$T_1(X) = X$$

$$T_2(X) = 2\,X^2 - 1$$

$$T_3(X) = 4\,X^3 - 3\,X$$

$$T_4(X) = 8\,X^4 - 8\,X^2 + 1$$

$$T_5(X) = 16\,X^5 - 20\,X^3 + 5\,X$$

$$T_6(X) = 32\,X^6 - 48\,X^4 + 18\,X^2 - 1$$

$$T_7(X) = 64\,X^7 - 112\,X^5 + 56\,X^3 - 7\,X$$

$$T_8(X) = 128\,X^8 - 256\,X^6 + 160\,X^4 - 32\,X^2 + 1$$

All the rate-coefficient and cross-section data in Sects. 1 and 2, and the rate coefficients in Sects. 3 and 5 may be reproduced by using either of the model Chebychev

fitting programs listed at the end of this Appendix. For each reaction and pair of reactants there are given Chebychev fitting parameters to be used as input to the CHBFIT Fortran or CHBFIT Basic code.

In the plots of recommended data the Chebychev or alternative fits have been added as dashed lines to give a visual inspection of the accuracy of the fit. Also, the cross section tables include rms deviations of the fit to the recommended data over the energy range from E_{min} to E_{max}.

The fitting programs require input of the parameters E_{min}, E_{max}, and the Chebychev coefficients C1, C2, ... C9 to enable calculation of a rate coefficient or cross section at a given energy. The programs direct the user to input these parameters at the proper time during program execution. To simplify data input, the tabulations of coefficients contain the minimum number of significant digits required to produce an accurate representation of the polynomial fit.

Sample FORTRAN Program

```
        PROGRAM CHBFIT
C       THIS FORTRAN PROGRAM IS DERIVED FROM A PROGRAM IN 'ELEMENTARY NUMERICAL
C       ANALYSIS: AN ALGORITHMIC APPROACH' , S.D. CONTE AND C. de BOOR,
C       McGRAW-HILL, INC., P 254, 1972.
        DIMENSION D(9)
        REAL*4 ANS
1000    TYPE 14
14      FORMAT('   IS THIS A RATE FIT ; ENTER "Y" FOR YES, "N" FOR NO')
        ACCEPT 199, ANS
199     FORMAT(A1)
        IF (ANS .EQ. 'Y') NTERMS=7
        IF (ANS .EQ. 'N') NTERMS=9
        IF (NTERMS .EQ. 7) TYPE 1
        IF (NTERMS .EQ. 9) GO TO 16
1       FORMAT(1H ,'********* ENTER Emin (eV) *********')
        ACCEPT *, EMIN
        TYPE 9
9       FORMAT(1H ,' ********* ENTER Emax (eV) *********')
        ACCEPT *, EMAX
        IF (NTERMS .EQ. 7) GO TO 25
16      TYPE 19
19      FORMAT(1H ,'********* ENTER Emin (eV/amu) *********')
        ACCEPT *, EMIN
        TYPE 29
29      FORMAT(1H ,'********* ENTER Emax (eV/amu) *********')
        ACCEPT *, EMAX
25      EMINL=ALOG(EMIN)
        EMAXL=ALOG(EMAX)
        TYPE 2, NTERMS
2       FORMAT(1H ,' ENTER ',I1,' COEFFICIENTS ')
        ACCEPT *,(D(J),J=1,NTERMS)
100     IF (NTERMS .EQ. 7) TYPE 3,EMIN,EMAX
3       FORMAT(' INPUT ENERGY (eV) BETWEEN',1PE10.1,' AND',1PE10.1,' FOR
     & THE RATE CALCULATION ')
        IF (NTERMS .EQ. 9) TYPE 23, EMIN, EMAX
23      FORMAT(' INPUT ENERGY (eV/amu) BETWEEN',1PE10.1,' AND',1PE10.1,'FOR
     & THE CROSS SECTION CALCULATION ')
C       GET ENERGY FOR CALCULATION AND USE THREE TERM RECURRENCE RELATION
        K=NTERMS
        CHEB=D(K)
        ACCEPT *,X
        IF(X .LT. 0.) GO TO 101
        X=ALOG(X)
        K=K-1
        IF(K .EQ. 0)    RETURN
        XNORM=(X-EMINL-(EMAXL-X))/(EMAXL-EMINL)
        TWOX=2.*XNORM
        PREV2=0.
10      PREV=CHEB
        IF(K .EQ. 1)    GO TO 20
        CHEB=D(K)+TWOX*PREV-PREV2
        PREV2=PREV
        K=K-1
        GO TO 10
20      CHEB=.5*D(1)+XNORM*PREV-PREV2
        IF(NTERMS .EQ. 7) TYPE 69, CHEB
69      FORMAT(1PE12.4,' = RATE COEFFICIENT (CM3/S)')
        IF (NTERMS .EQ. 9) TYPE 45, CHEB
45      FORMAT(1PE12.4,' = CROSS SECTION(CM2)')
        TYPE 48
48      FORMAT(' DO YOU WANT ANOTHER CALCULATION FOR THIS FIT?, ENTER "Y"
     & FOR YES; "N" FOR NO')
        ACCEPT 199,ANS
        IF(ANS .EQ. 'Y') GO TO 100
        TYPE 49
49      FORMAT(' DO YOU WANT A DIFFERENT FIT CALCULATION?, ENTER "Y"
     &  FOR YES;"N" FOR NO')
        ACCEPT 199, ANS
        IF(ANS .EQ. 'Y') GO TO 1000
101     RETURN
        END
```

Sample BASIC Program

```
10 REM   CHBFIT PROGRAM IS A BASIC PROGRAM DERIVED FROM A FORTRAN PROGRAM IN
20 REM   "ELEMENTARY NUMERICAL ANALYSIS: AN ALGORITHMIC APPROACH", S. D. CONTE
30 REM   AND C. de BOOR, McGRAW-HILL, INC., P 254, 1972.
40       DIM D(9)
50       INPUT "IS THIS A RATE FIT?; ENTER 'Y' FOR YES, 'N' FOR NO   ",ANS$
60       IF ANS$="Y" THEN NTERMS=7:ELSE NTERMS=9
70       IF NTERMS=7 THEN INPUT"ENTER Emin (eV)   ",EMIN
80       IF NTERMS=7 THEN INPUT"ENTER Emax (eV)  ",EMAX
90       IF NTERMS=9 THEN INPUT"ENTER Emin (eV/amu)   ",EMIN
100      IF NTERMS=9 THEN INPUT"ENTER EMAX (eV/amu)",EMAX
110      EMINL=LOG(EMIN)
120      EMAXL=LOG(EMAX)
130      PRINT USING "ENTER # COEFFICIENTS";NTERMS
140      FOR J=1 TO NTERMS
150      INPUT D(J):NEXT J
160      IF NTERMS = 7 THEN PRINT USING "INPUT ENERGY (eV) BETWEEN ###.# AND #.#^
^^^ FOR THE RATE COEFFICIENT CALCULATION";EMIN;EMAX
170      IF NTERMS = 9 THEN PRINT USING "INPUT ENERGY (eV/amu) BETWEEN ###.# AND
#.#^^^^  FOR THE CROSS SECTION CALCULATION";EMIN;EMAX
180      REM  GET ENERGY FOR CALCULATION AND USE THREE TERM RECURRENCE RELATION
190      INPUT X
200      K=NTERMS
210      CHEB=D(K)
220      IF X<0 THEN END
230      X=LOG(X)
240      K=K-1
250      IF K=0 THEN END
260      XNORM=(X-EMINL-(EMAXL-X))/(EMAXL-EMINL)
270      TWOX=2*XNORM
280      PREV2=0
290      PREV=CHEB
300      IF K=1 GOTO 350
310      CHEB=D(K)+TWOX*PREV-PREV2
320      PREV2=PREV
330      K=K-1
340      GOTO 290
350      CHEB=.5*D(1)+XNORM*PREV-PREV2
360      IF NTERMS=7 THEN PRINT USING"##.##^^^^ = RATE COEFFICIENT (CM3/S)";CHEB
370      IF NTERMS=9 THEN PRINT USING"##.##^^^^ = CROSS SECTION (CM2)";CHEB
380      INPUT "DO ANOTHER ENERGY?, ENTER 'Y'FOR YES;'N' FOR NO",ANS$
390      IF ANS$="Y" THEN GOTO 160
400      INPUT "DO A DIFFERENT FIT?, ENTER 'Y' FOR YES;'N' FOR NO  ",ANS$
410      IF ANS$="Y" THEN GOTO 50
420      END
```

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